

ASME Sec. IX (Ed.2019) Latest Edition

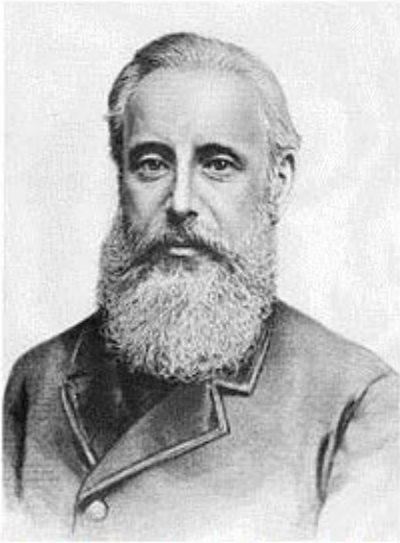


ASME

American Society of Mechanical Engineers

- ❑ ASME was founded (in New York) in 1880 in response to numerous steam boiler pressure vessel failures.
- ❑ First performance test code of Steam Boilers trail was conduct in 1884.
- ❑ First revision of an ASME standard was made in 1900 .
- ❑ ASME has over 140,000 members in 158 countries worldwide .
- ❑ It produces approximately 600 codes and standards covering many technical areas.

ASME Founders



Henry Rossiter Worthington



Alexander Lyman Holley



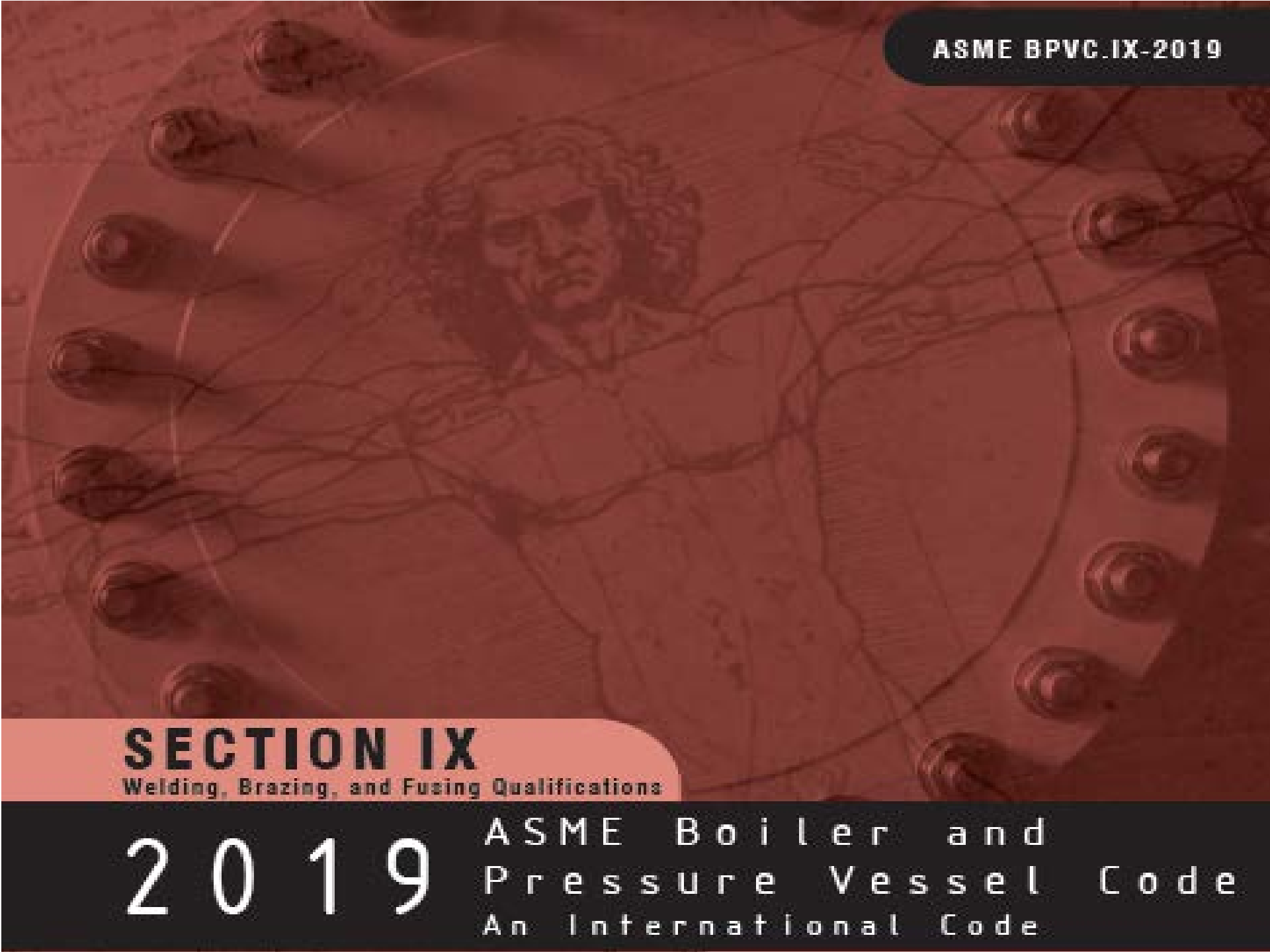
John Edson Sweet

ASME BPVC Codes

- | | |
|---|---------------------|
| ☐ ASME Section I | – Power Boilers |
| ☐ ASME Section II Part A | |
| ASME Section II Part B | – Materials |
| ASME Section II Part C | |
| ASME Section II Part D | |
| ☐ ASME Section III | – Nuclear Codes |
| ☐ ASME Section IV | – Heating Boilers |
| ☐ ASME Section V | – NDE |
| ☐ ASME Section VIII Div. 1 | |
| ASME Section VIII Div. 2 | – Pressure Vessel |
| ASME Section VIII Div. 3 | |
| ☐ ASME Section IX | – Welding & Brazing |
| ☐ ASME B31.3 | – Process Piping |
| ☐ ASME B31.1 | – Power Piping |

ASME BPVC Timeline

- ❑ 1911 – ASME set up the B&PV Committee – to formulate std rules for construction of boilers and pressure vessel
- ❑ 1915 – First Code issued – ASME 1 – Power Boilers
- ❑ 1923 – Heating Boilers – Section IV
- ❑ 1924 – Materials – Section II
- ❑ 1925 – Pressure Vessel – Section VIII Div. 1
- ❑ 1941 – **Welding & Brazing – Section IX (Latest Ed.2019)**
- ❑ 1963 – Nuclear Codes – Section III
- ❑ 1968 – Pressure Vessel – Section VIII Div. 2
- ❑ 1971 – NDE – Section V
- ❑ 1997 – Pressure Vessel – Section VIII Div. 3



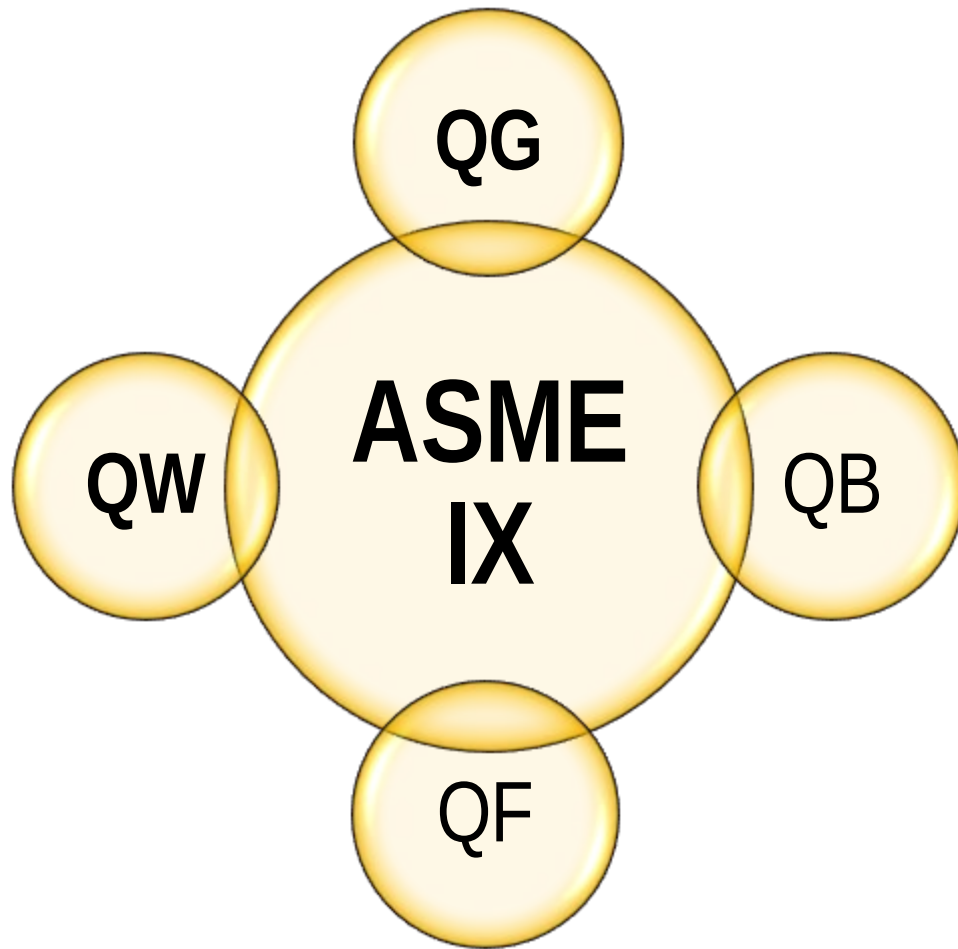
ASME BPVC.IX-2019

SECTION IX

Welding, Brazing, and Fusing Qualifications

2019

ASME Boiler and
Pressure Vessel Code
An International Code



QG:	General Requirements
QW:	Welding
QB:	Brazing
QF :	Plastic Fusing

QG (General Requirements)

QG - General Requirements

QG-100 (a): Scope

This Section contains requirements for the **Welders and Welding Operators Qualification, Brazers and Brazing Operators, Plastic Fusing Operators**, and the **Material Joining Processes** they use during welding, brazing, and fusing operations for the construction of components.

❑ ASME Boiler and Pressure Vessel and piping codes and other codes, standards, and specifications that reference this Section.

QG - General Requirements

QG-100 (b): Whenever there will be a conflict between referencing Code, standard, or specification and this section (IX) the requirements of the referencing Code, standard, or specification shall take precedence over the requirements of this section.

QG-100 (c): Whenever the word “pipe” is used, “tube” shall also be applicable.

QG-100 (d): New editions to Section IX becomes mandatory 6months after the date of issuance.

QG-100 (e): Code Cases are permissible and may be used, beginning with the date of approval by ASME.

(See details in code)

QG - General Requirements

QG-101: Procedure Specification (WPS)

❑ A procedure specification is a written document providing direction to the person applying the material joining process.

❑ As a minimum, WPS shall document essential, Non essential variables applied during production of the test joint, and the results of the required tests.

(Also Supplementary essential Variables when applicable)

❑ Organization shall be responsible for this specification.

➡ One WPS may be supported by one or more PQR(s).

QG - General Requirements

QG-102: Procedure Qualification Record (PQR)

❑ Demonstrate that joining process proposed for construction is capable of producing joints having the required mechanical properties for the intended application.

❑ As a minimum, PQR shall document essential variables applied during production of the test joint, and the results of the required tests.

(Also Supplementary essential Variables when applicable)

➡ One PQR may be used to support one or more WPS(s).

QG - General Requirements

QG-103: Performance Qualification (WQT)

Demonstration that person's ability to produce a sound joint when using a procedure specification.

QG-104: Performance Qualification Record

As a minimum, the record shall document

- a) Essential variables
- b) Ranges of variables qualified
- c) Results of required testing and NDE
- d) Identification of the procedure specification(s) followed during the test

QG - General Requirements

QG-106: Organizational Responsibility

QG-106.3: Simultaneous Performance Qualifications

Organizations may participate in an association to collectively qualify the performance of one or more persons for material-joining processes simultaneously and may share performance qualification information with other participating organizations within the association.

QG - General Requirements

QG-107: Ownership Transfers

- ❑ Multiple organizations under a common ownership may use PQRs, WPS, and performance qualification records under that owner's name.
- ❑ New owner(s) may acquire these documents without requalification. Following shall be meet:
 - a) Takes responsibility
 - b) WPS identify name of new owner
 - c) QC system & QA program documents original source

QG - General Requirements

QG-108: Qualifications Made To Previous Editions

☐ Qualification that were made in accordance with Editions and Addenda as far back as 1962 Edition may be used in any construction for which current Edition has been specified.

(All requirements of shall meet)

☐ Qualification records meeting the above requirements do not require amendment to include any variables required by later Editions and Addenda, except as specified in **QW-420**.

(Revised P or G number in latest Ed.)

QG - General Requirements

QG-109: Definitions

Back Gouging:

Removal of weld metal and base metal from the weld root side of a welded joint to facilitate complete fusion and complete joint penetration upon subsequent welding from that side.



QG - General Requirements

Backing:

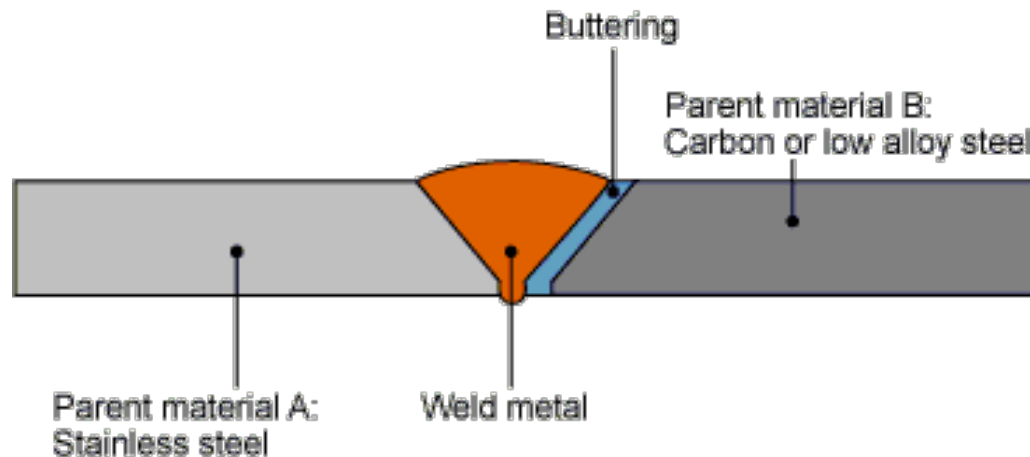
A material placed at the root of a weld joint for the purpose of supporting molten weld metal so as to facilitate complete joint penetration. The material may or may not fuse into the joint.
(Argon, Helium, Nitrogen)

➔ **API 582_7.3:** Back purging is required for the GTAW and GMAW processes for welding materials having a nominal chromium content greater than 2-1/4 % unless the joint is ground or back gouged to sound metal.

QG - General Requirements

Buttering:

Addition of material, by welding, on one or both faces of a joint, prior to the preparation of the joint for final welding, for the purpose of providing a suitable transition weld deposit for the subsequent completion of the joint.



QG - General Requirements

P Number: (Essential Variable)

Assigned to the materials based their similarity and characteristic such as chemical compositions, weldability and mechanical property.

(See QW-420, Table QW-422)

Table QW/QB-422
Ferrous and Nonferrous P-Numbers
Grouping of Base Metals for Qualification (Cont'd)

Spec. No.	Designation, Type, or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding		Brazing		Nominal Composition	Typical Product Form	
				P-No.	Group No.	P-No.	AWS			ISO 15608
							B2.2 BM			Group
						Ferrous (Cont'd)				
A/SA-516	55	K01800	55 (380)	1	1	101	100	1.1	C-Si	Plate
A/SA-516	60	K02100	60 (415)	1	1	101	100	1.1	C-Mn-Si	Plate
A/SA-516	65	K02403	65 (450)	1	1	101	100	1.1	C-Mn-Si	Plate
A/SA-516	70	K02700	70 (485)	1	2	101	100	11.1	C-Mn-Si	Plate

QG - General Requirements

Group Number:

Divide a P number to several group numbers for the purpose of welding procedure qualification when impact testing is a requirement by the construction code. (**ASME VIII UCS-66, UG-84**)

(See **QW-420** for base metal grouping, **Table QW-422**)

S Number:

These are the listing of those materials which have been included by **ASME B31** code or by selected ASME boiler and pressure vessel code cases but are not included in ASME boiler and pressure vessel code material specifications (**ASME Sec. II**).

Purpose is the same as of P-numbers.

QG - General Requirements

F number: (Essential Variable)

This grouping is made to reduce the number of welding procedure and performance qualifications.

(See Table QW-432 for F nos. and QW-433 for F nos. Qualification)

Base Metal	P - No.	Electrode	SFA	F - No.
A106-Gr.B	P1	E7018	A5.1	4
A312- TP316	P8	E309	A5.9	6

Table QW-353
Shielded Metal-Arc Welding (SMAW)
Essential Variables

Paragraph		Brief of Variable
Filler Metals QW-404	.15	ϕ F-Number

Qualified With →	F-No. 1 With Backing	F-No. 1 Without Backing	F-No. 2 With Backing	F-No. 2 Without Backing	F-No. 3 With Backing	F-No. 3 Without Backing	F-No. 4 With Backing	F-No. 4 Without Backing	F-No. 5 With Backing	F-No. 5 Without Backing
Qualified For ↓										
F-No. 4 Without Backing								X		

QW-433

Qualified With

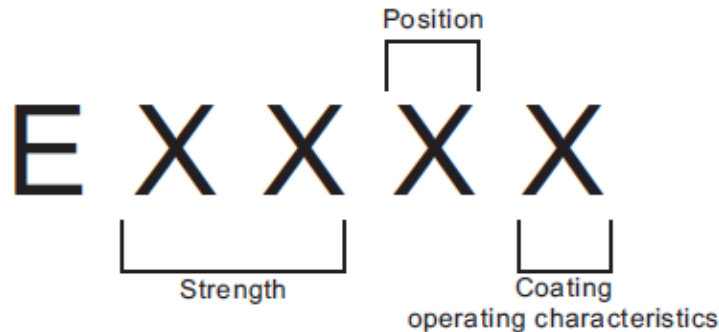
Any F-No. 6

Qualified For

All F-No. 6

QG - General Requirements

E 7 0 1 8



API 577

Figure A.6—SMAW Welding Electrode Identification System

ER 70 S - 3

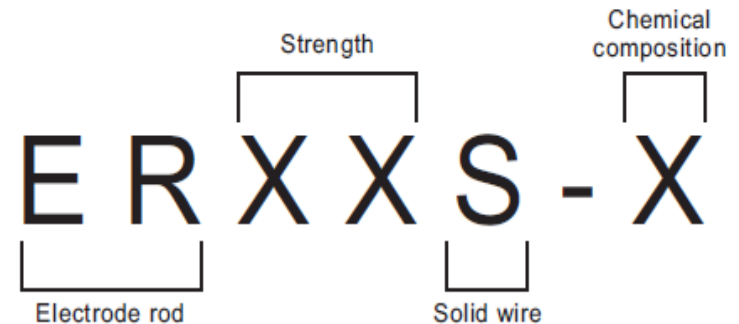


Figure A.7—GMAW/GTAW/PAW Welding Electrode Identification System
API 577

API 582 Table 2—Diffusible Hydrogen Limit for FCAW Electrodes

Specified Minimum Tensile Strength for the Base Metal	Maximum Diffusible Hydrogen Designation (per ASME/AWS SFA/A5.20 or SFA/A5.29)
≤ 70 ksi (483 MPa)	H16
> 70 ksi (483 MPa) and ≤ 85 ksi (587 MPa)	H8
> 85 ksi (587 MPa)	H4

QG - General Requirements

Filler Metal Selection (7.6_API 577 Ed.2013)

Inspectors should verify the filler metal selection is appropriate for the base metal being welded.

Some considerations in selection include:

- a) Chemical composition of filler metal
- b) Tensile strength of filler metal and base metal
- c) Dilution of alloying elements from base metal
- d) Hardenability of filler metal
- e) Susceptibility to hot cracking
- f) Corrosion resistance of filler metal

QG - General Requirements

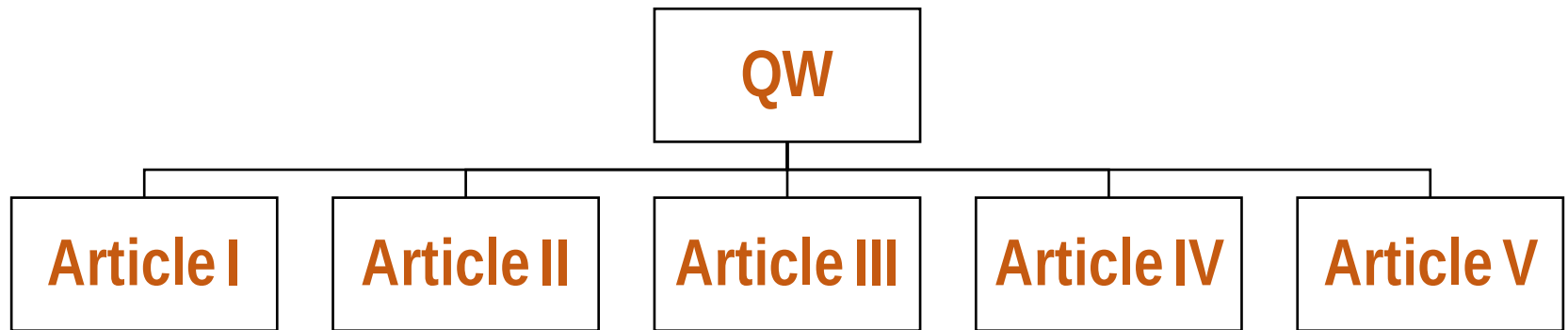
A Number: (Essential Variable)

P is groupings of base metals with similar weldability. F numbers are groupings of filler metals, and A numbers are weld deposit.

Table QW-442
A-Numbers
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)] and [Note (2)]					
		C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	0.20	0.30	0.50	1.60	1.0
2	Carbon-Molybdenum	0.15	0.50	0.40-0.65	0.50	1.60	1.0
3	Chrome (0.4% to 2%)-Molybdenum	0.15	0.40-2.00	0.40-0.65	0.50	1.60	1.0
4	Chrome (2% to 4%)-Molybdenum	0.15	2.00-4.00	0.40-1.50	0.50	1.60	2.0
5	Chrome (4% to 10.5%)-Molybdenum	0.15	4.00-10.5	0.40-1.50	0.80	1.20	2.0
6	Chrome-Martensitic	0.15	11.0-15.0	0.70	0.80	2.00	1.0
7	Chrome-Ferritic	0.15	11.0-30.0	1.00	0.80	1.00	3.0
8	Chromium-Nickel	0.15	14.5-30.0	4.00	7.50-15.0	2.50	1.0
9	Chromium-Nickel	0.30	19.0-30.0	6.00	15.0-37.0	2.50	1.0
10	Nickel to 4%	0.15	0.50	0.55	0.80-4.00	1.70	1.0
11	Manganese-Molybdenum	0.17	0.50	0.25-0.75	0.85	1.25-2.25	1.0
12	Nickel-Chrome—Molybdenum	0.15	1.50	0.25-0.80	1.25-2.80	0.75-2.25	1.0

QW (Welding)



Article I: Welding General Requirements

Article II: Welding procedure Qualification

Article III: Welding Performance Qualification

Article IV: Welding Data

Article V: Standard Welding Procedure Specifications (SWPSs)

QW - Welding

Article I:

Welding General Requirements

QW-100:	Scope
QW-110:	Welding Orientation
QW-120:	Tests Position for Groove Welding
QW-130:	Tests Position for Fillet Welding
QW-140:	Types and purpose of Test and Examinations
QW-150:	Tension Tests
QW-160:	Guided Bend Tests
QW-170:	Toughness Test
QW-180:	Fillet Weld Tests
QW-190:	Other Tests and Examinations
QW-193:	Tube to Tube sheet Tests
QW-194:	Visual Inspection
QW-195:	Liquid Penetration

QW - Welding

Article II: Welding Procedure Qualification

QW-200: General

QW-210: Preparation of test coupon

QW-220: Hybrid Welding Procedure Verifiable

QW-250: Welding Variables

QW-290: Temper Bead Welding

QW - Welding

Article III:	Welding Performance Qualification
QW-300:	General
QW-310:	Qualification Test Coupons
QW-320:	Retests and Renewal of Qualification
QW-350:	Welding Variables for Welders
QW-360:	Welding Variables for Welding Operators
QW-380:	Special Process

QW - Welding

Article IV: **Welding Data**

QW-400: Variables

QW-410: Technique

QW-420: Base Metal Groupings

QW-430: F-Number

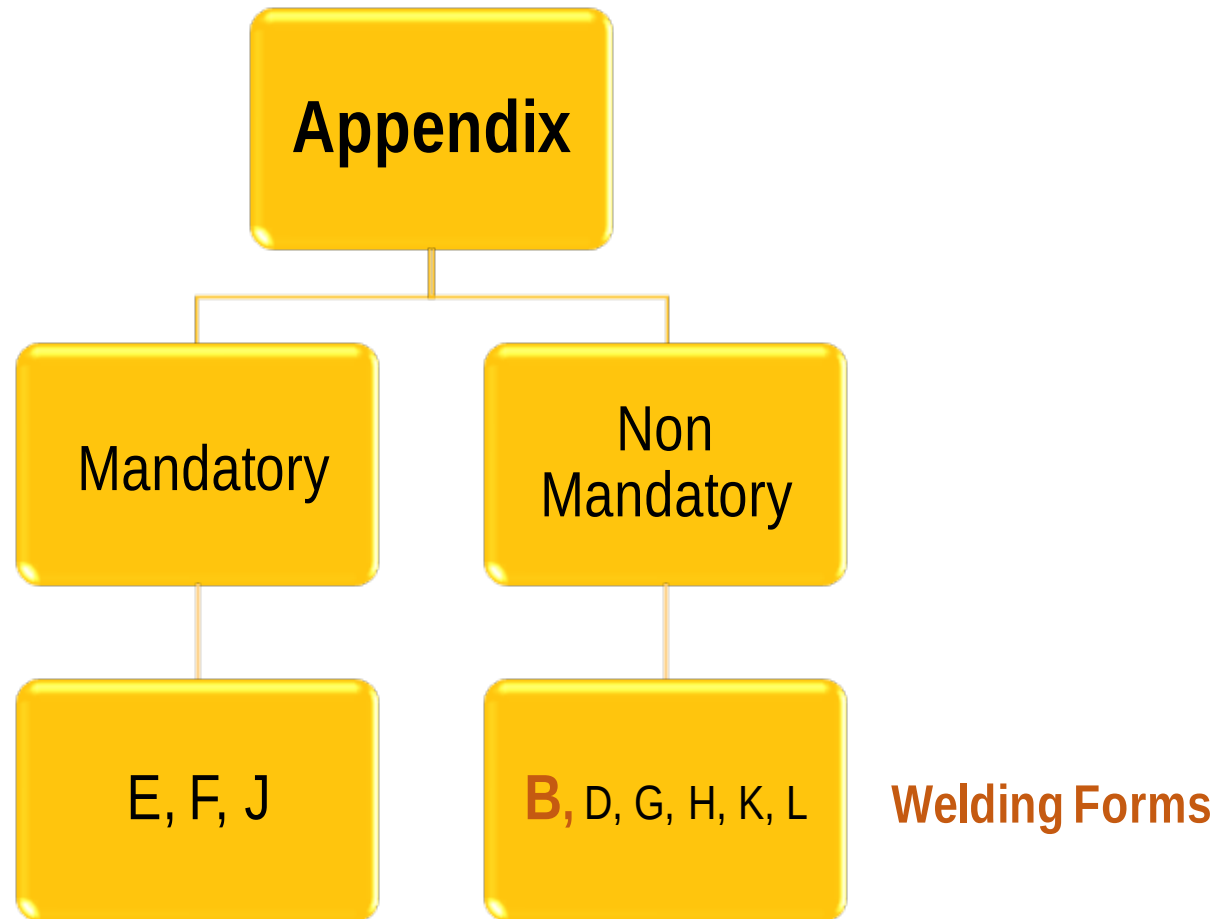
QW-440: Weld Metal Chemical Compositions

QW-450: Specimens

QW-460: Graphics

QW-470: Etching – Processes and Reagents

QW - Welding



Article I

Welding General Requirmnets

QW - Welding

Article I:	Welding General Requirmnets
QW-100:	Scope
QW-110:	Welding Orientation
QW-120:	Tests Position for Groove Welding
QW-130:	Tests Position for Fillet Welding
QW-140:	Types and purpose of Test and Examinations
QW-150:	Tension Tests
QW-160:	Guided Bend Tests
QW-170:	Toughness Test
QW-180:	Fillet Weld Tests
QW-190:	Other Tests and Examnations
QW-193:	Tube to Tube sheet Tests
QW-194:	Visual Inspection
QW-195:	Liquid Penetration

QW - Welding (Article I)

QW-100: Scope

This article apply to the preparation of Welding Procedure Specifications (WPS) and the qualification of welding procedures, welders, and welding operators for all types of manual and machine welding processes permitted in this Part.

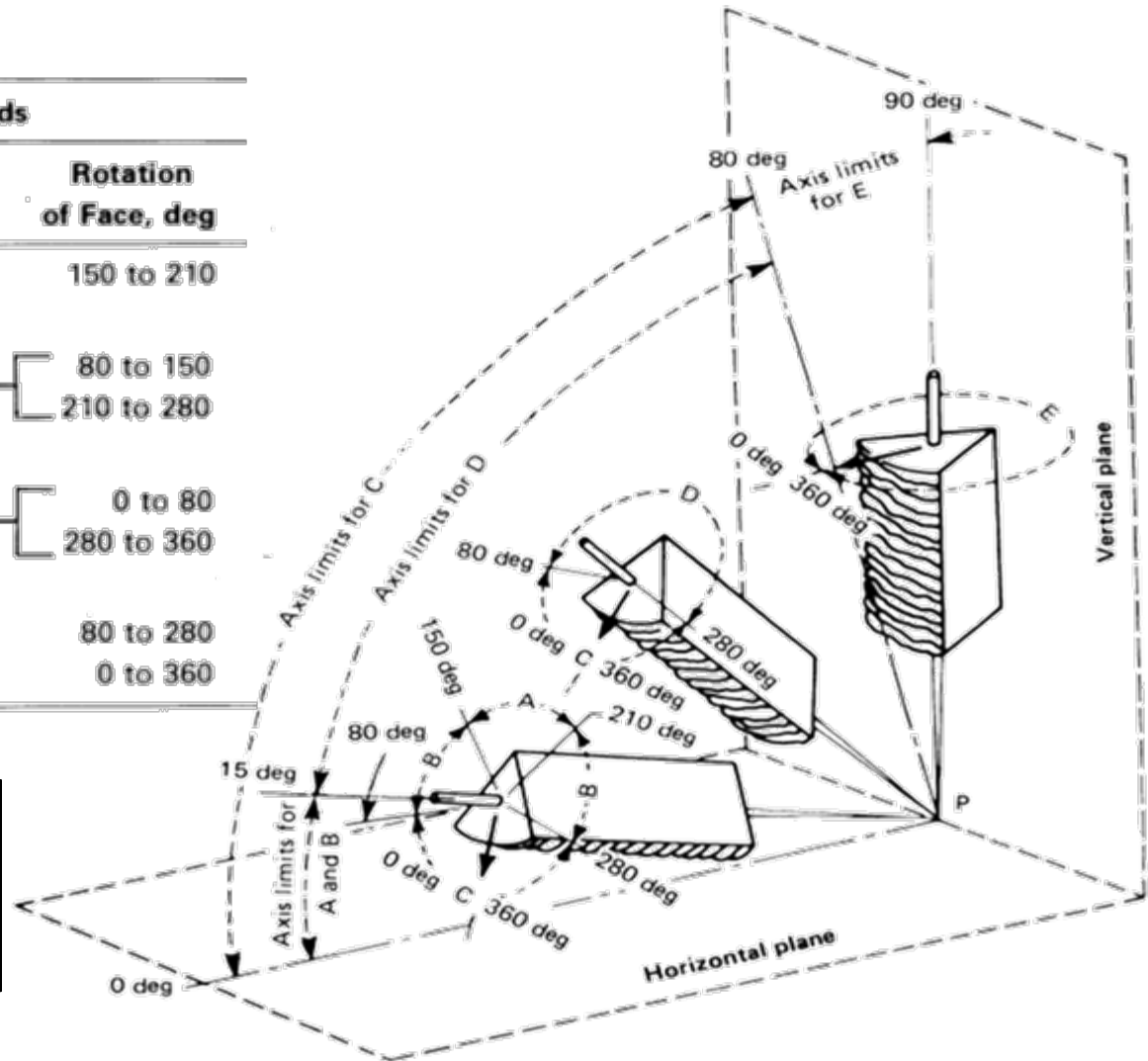
QW - Welding (Article I)

QW-110: Weld Orientation

Tabulation of Positions of Welds

Position	Diagram Reference	Inclination of Axis, deg	Rotation of Face, deg
Flat	A	0 to 15	150 to 210
Horizontal	B	0 to 15	80 to 150
			210 to 280
Overhead	C	0 to 80	0 to 80
			280 to 360
Vertical	D	15 to 80	80 to 280
	E	80 to 90	0 to 360

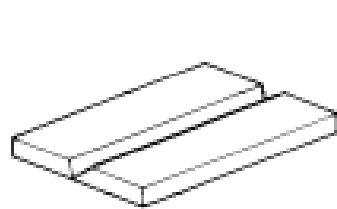
Figure QW-461.1
Positions of Welds —
Groove Welds



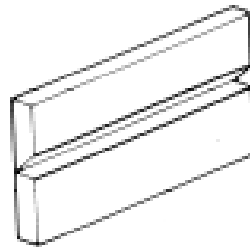
QW - Welding (Article I)

QW-120: Tests Position for Groove Welding

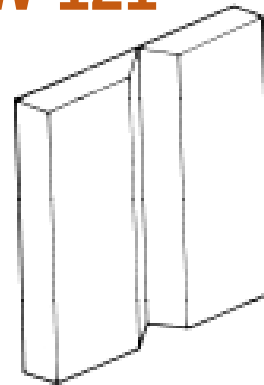
Figure QW-461.3
Groove Welds in Plate — Test Positions



(a) 1G



(b) 2G



(c) 3G



(d) 4G

Figure QW-461.4
Groove Welds in Pipe — Test Positions



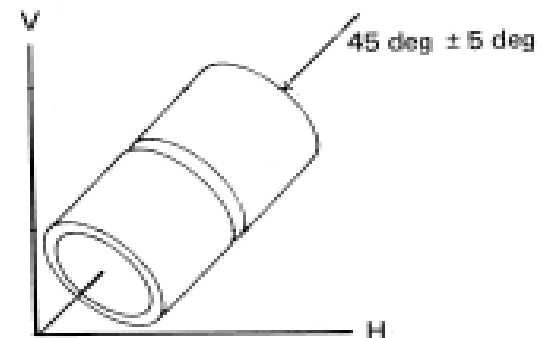
(a) 1G (Rotated)



(b) 2G



(c) 5G



(d) 6G

QW-121

QW-122

QW - Welding (Article I)

QW-120: Tests Position for Groove Welding

Angular deviation of ± 15 deg from the specified horizontal and vertical planes, and an angular deviation of ± 5 deg from the specified inclined plane are permitted during welding.

QW - Welding (Article I)

QW-140: Types and purpose of Test and Examinations

Mechanical Test		Non Destructive Examination
Groove Weld	Fillet Welds	Groove/Fillet Welds
Tension Test (QW-150)	Fracture Test (QW-182)	Radiography Test (QW-191.1)
Guide Bend Test (Longitudinal and Transverse) (QW-160)	Macro Examination (QW-183)	Ultrasonic Test (QW-191.2)
Toughness Test (QW-170) (Impact Test)	-	Liquid Penetration (QW-195)

QW - Welding (Article I)

QW-150: Tension Test (Nos. of required test given in **Table QW-451**)

☐ To determine the ultimate tensile strength on the weld section.

QW-151.1(a)/QW-151.2(a): For thicknesses up to and including 1 in. (25 mm), a full thickness specimen shall be used.

QW-151.1(b)/QW-151.2(b): For thickness greater than 1 in. (25 mm), full thickness specimens or multiple specimens may be used.

QW-151.4 : Full section specimens for pipe may be used for testing pipe with an outside diameter of 3 in. (75 mm) or less.

QW - Welding (Article I)

QW-150: Tension Test

QW-451: Required Number of Tensile Tests

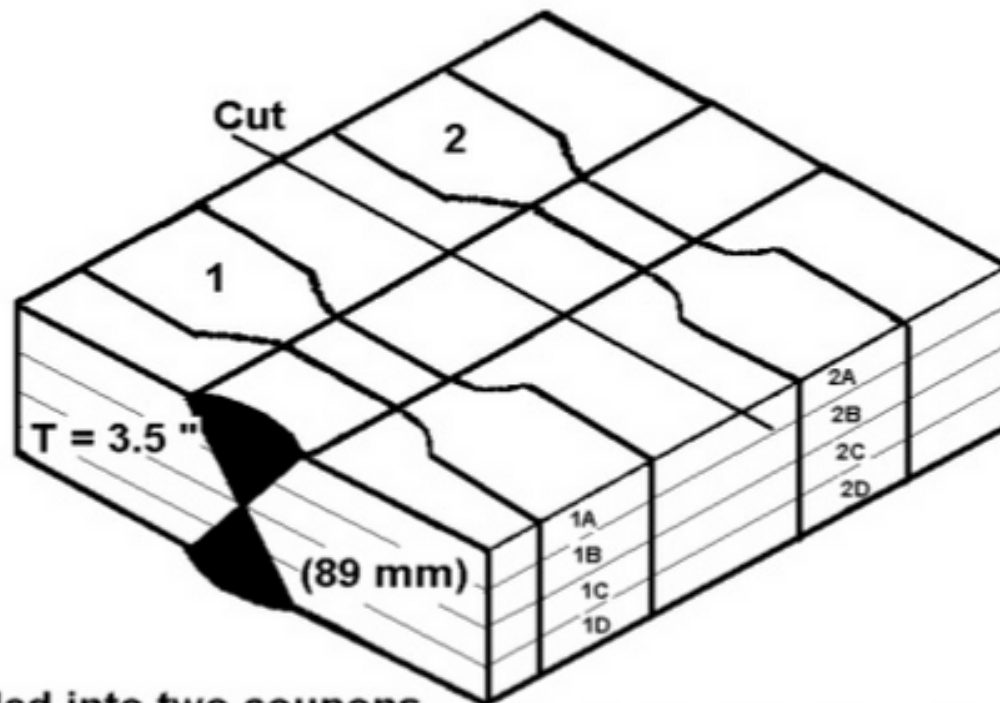
From Table QW-451.1 (For Procedure Qualification)	
Thickness of Test Coupon, Welded (mm)	Required Number of Tension Test
Less than 1.5	02
1.5 to 10 incl.	02
10 but less than 19	02
19 to less than 38	02
38 to 150 , incl.	02
Over 6 (150)	02
Note : See QW-151.1, QW-151.2, and QW-151.3 for details on multiple specimens when coupon thicknesses are over 1 in. (25 mm) .	

QW - Welding (Article I)

QW-150: Tension Test



QW – 151.1 Reduced Section – Plate
Example: 3.5" (89 mm) in 1" (25 mm) Capacity TS Machine



Divided into two coupons
each 4 specimens
All eight must pass!

Tensile Machine Capacity
1" (25 mm) Maximum

QW - Welding (Article I)

QW-153 : Acceptance Criteria of Tension Test

QW153.1(a): Minimum specified tensile strength of the base metal. (See ASME II-A or Table QW-422)

QW153.1(b): Weaker of the two base metals.

(if base metals of different minimum tensile strengths are used)

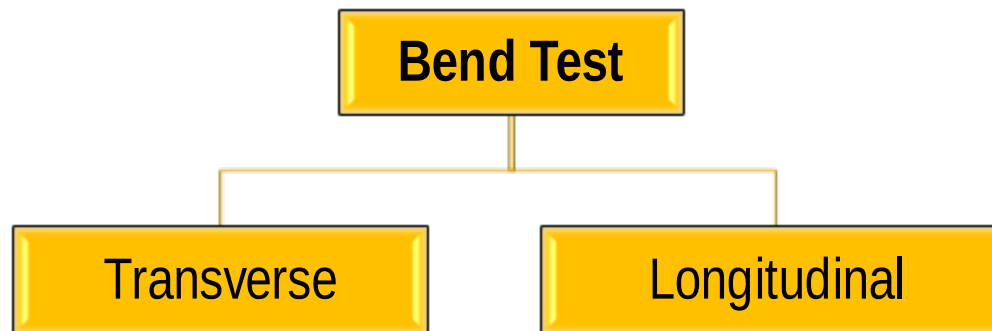
QW153.1(d): Strength is not more than 5% below the minimum specified tensile strength of the base metal.

➡ No need for retest if specimen breaks in the base metal outside of the weld or weld interface.

QW - Welding (Article I)

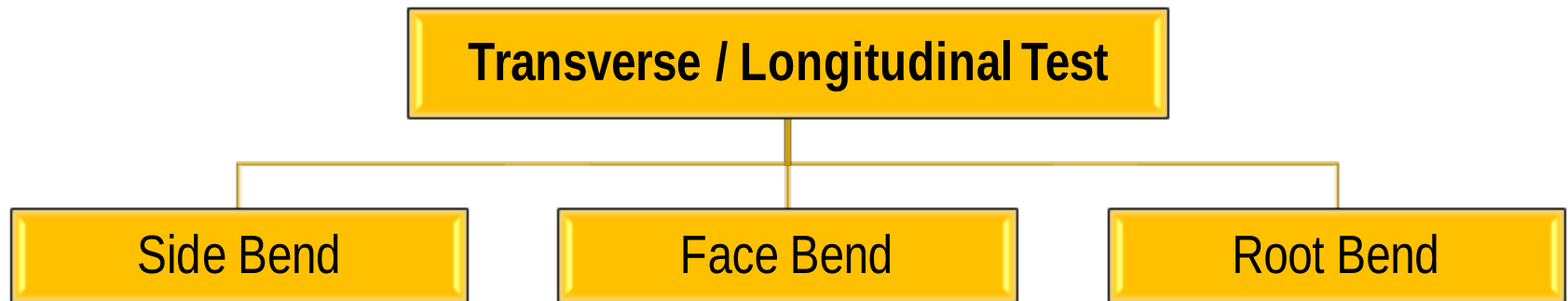
QW-160: Guided Bend Test

- ❑ To determine the ductility of weld metal at the face and root of a welded joint.
- ❑ Test shall be prepared by cutting the test plate or pipe to form specimens of approximately rectangular cross section
- ❑ The specimen thickness and Bend Radius are shown in **Figures QW-466.1, QW-466.2, and QW-466.3.**



QW - Welding (Article I)

QW-160: Guided Bend Test



QW - Welding (Article I)

QW-160: Guided Bend Test

QW-161.1: Transverse Side Bend

One side of the weld surfaces becomes convex.

(Specimens of base metal thickness equal to or greater than 38mm may be cut into approximately equal strips between 19 mm and 38 mm wide for testing).

(See Figure QW-462.2 for specimen)

QW-161.2: Transverse Face Bend

Weld Face becomes convex

(See Figure QW-462.3(a) for specimen)

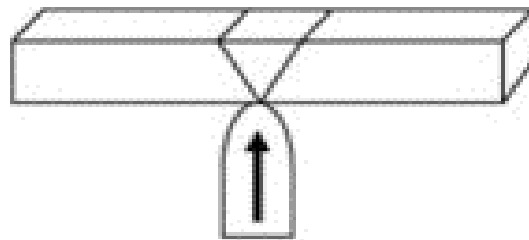
QW-161.3: Transverse Root Bend

Weld Root becomes convex

(See Figure QW-462.3(a) for specimen)

QW - Welding (Article I)

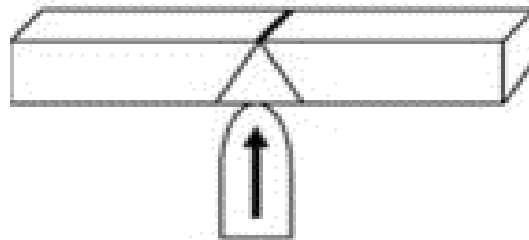
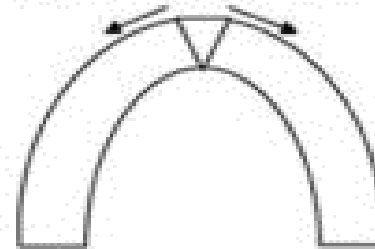
QW-160: Guided Bend Test



Face bend

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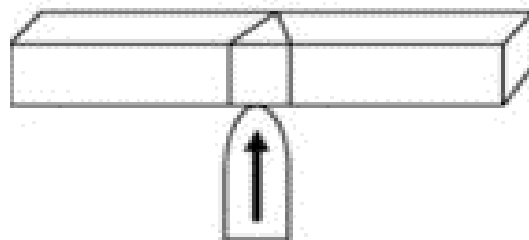
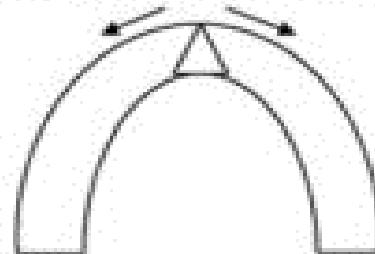
Weld face under tension



Root bend

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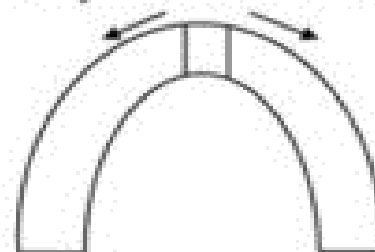
Weld root under tension



Side bend

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Weld profile under tension



QW - Welding (Article I)

QW-160: Guided Bend Test

QW-161.5: Longitudinal bend tests may be used in lieu of the transverse. When differ markedly in Bending properties between

- a) Two base metals, or
- b) Weld metal and the base metal

QW-162.1: Precaution During Bend Test

- ☐ The specimen shall be forced into the die by applying load on the plunger until the curvature of the specimen is such that a 3 mm diameter wire cannot be inserted between the specimen and the die.
- ☐ When specimens wider than 38mm are to be bent as permitted in **Figure QW 462.2**, Test jig mandrel must be at least 6mm wider than the specimen width.
- ☐ The weld and heat-affected zone of a transverse weld bend specimen shall be completely within the bent portion of the specimen after testing.

QW - Welding (Article I)

QW-160: Guided Bend Test

QW-163: Acceptance Criteria Bend Tests

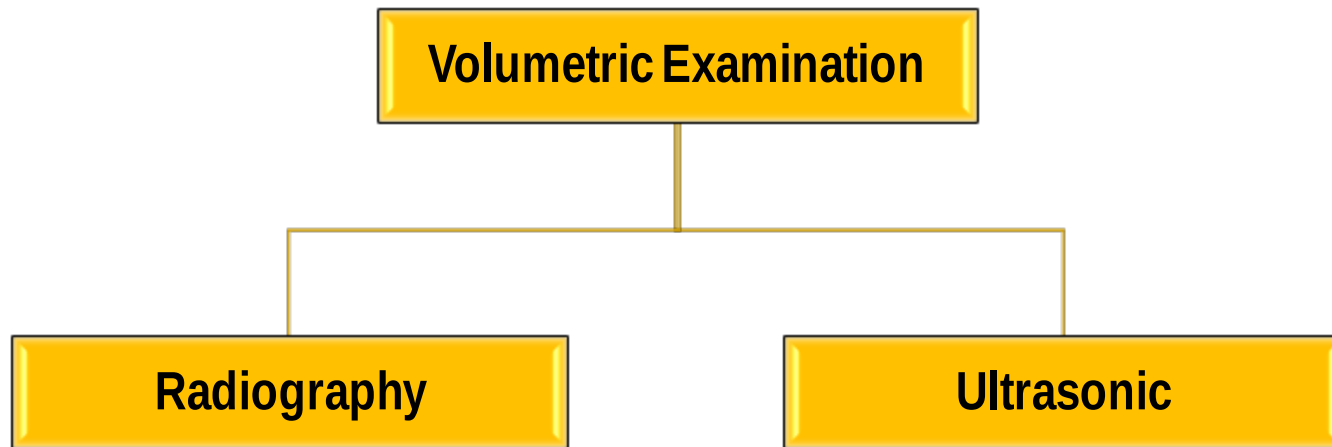
☐ Specimens shall have no open discontinuity in the weld or heat-affected zone exceeding 3mm.

Measured in any direction on the convex surface of the specimen after bending.

☐ Open discontinuities occurring on the corners of the specimen during testing shall not be considered unless there is definite evidence that they result from lack of fusion, slag inclusions, or other internal discontinuities

QW - Welding (Article I)

QW-190: Other Tests and Examinations (RT, UT)



QW-142:

☐ Radiographic or Ultrasonic examination per **QW-191** may be substituted for mechanical testing of **QW-141** for groove-weld performance qualification.

➡ Except welding process GMAW_ Short circuiting mode for radiographic examination. (**See: QW-304**)

QW - Welding (Article I)

QW-190: Other Tests and Examinations (RT, UT)

QW-191.1: Radiographic Examination

Shall meet the requirements of **ASME V, Article 2**, except as follows:

- a) A written radiographic examination procedure is not required.
- b) Final acceptance of radiographs shall be based on the ability to see the prescribed image and the specified hole of a hole-type image quality indicator (IQI) or the designated wire of a wire-type IQI.

QW - Welding (Article I)

QW-191.1.2 : Radiography Acceptance Criteria

1- QW191.1.2.1 (a): Linear Indication

(In which the length is more than three times the width)

- a) Cracks
 - b) Incomplete fusion
 - c) Inadequate penetration
 - d) Slag
- **t** : is the thickness of the weld excluding any allowable reinforcement.

QW-191.1.2.2 (a): Qualification Test Welds

- 1) Incomplete fusion or Penetration are unacceptable.
- 2) Elongated slag inclusion which has a length greater than
 - (2-a) 3 mm for t up to 10 mm, inclusive
 - (2-b) $\frac{1}{3} t$ for t over 10 mm to 57 mm, inclusive
 - (2-c) 19 mm for t over 57 mm
- 3) For Slag Inclusion see **QW-191.1.2.2 (a)(3)**

QW - Welding (Article I)

QW-191.1.2 : Radiography Acceptance Criteria

2- QW191.1.2.1(b): Rounded Indication

(In which the length is three times the width or less)

- a) Circular
- b) Elliptical
- c) Irregular in shape; may have tails; and may vary in density

QW-191.1.2.2(b): Qualification Test Welds

- 1) Indication 20% of t or 3 mm whichever is smaller
- 2) $T < 3\text{mm}$, 12 indications acceptable in 150mm length
- 3) $T > 3\text{mm}$ Indication $< 0.8\text{ mm}$ in diameter shall not be considered

➡ See **Figure QW-191.1.2.2(b)(4)** Rounded Indication Charts.

QW - Welding (Article I)

QW-190: Other Tests and Examinations (RT, UT)

QW-191.2.1: Ultrasonic Examination

Shall meet the requirements of **Section V, Article 4.**

In use when test welds in material 6 mm thick or greater .

[See QW-191.2.1 (a)]

QW-191.2.3: Acceptance Criteria for Qualification

- 1) Cracks, lack of fusion, incomplete penetration are unacceptable
- 2) Indications exceeding 3 mm in length are considered relevant, and are unacceptable when their lengths exceed
 - (2-a) 3 mm for t up to 10 mm, inclusive
 - (2-b) $\frac{1}{3} t$ for t over 10 mm to 57 mm, inclusive
 - (2-c) 19 mm for t over 57 mm

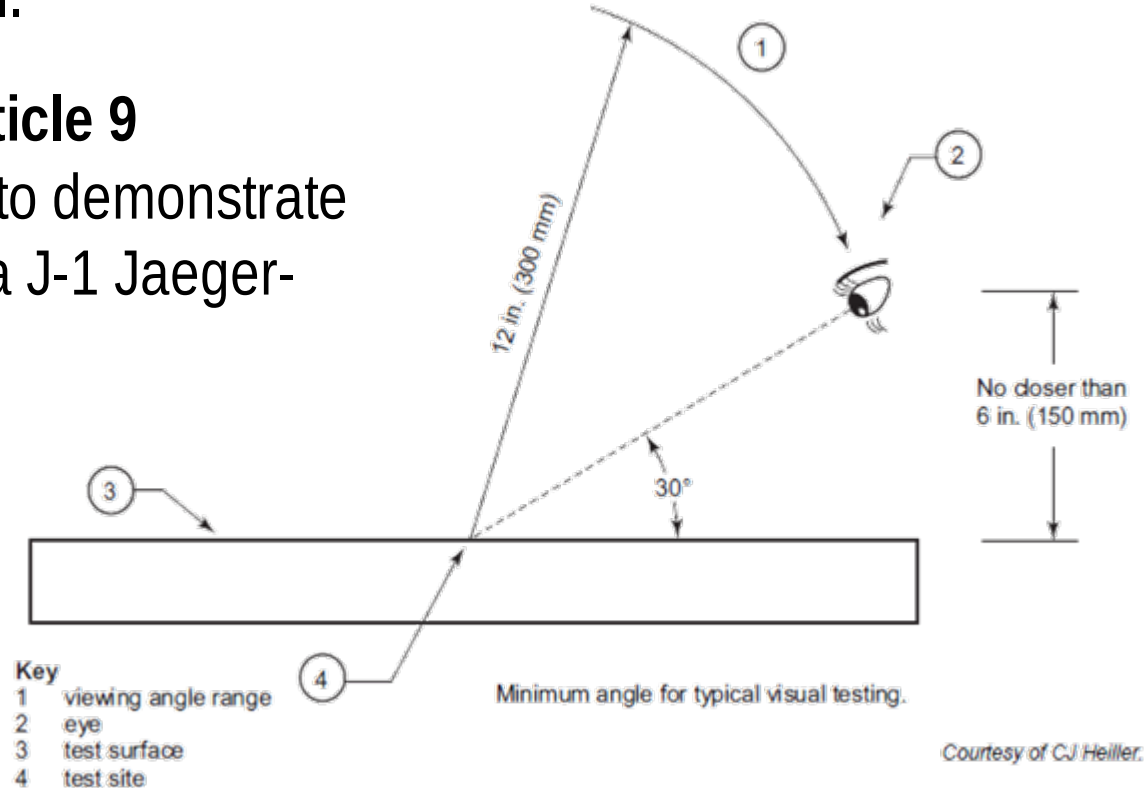
QW - Welding (Article I)

QW-194: Visual Examination Performance

- Performance test coupons shall show **No Cracks** and **Complete Joint Penetration** with **Complete Fusion Of Weld** Metal and base metal.

► ASME Section V, Article 9

Personnel are required to demonstrate annually completion of a J-1 Jaeger-type eye vision test.



QW - Welding (Article I)

QW-195: Liquid Penetrant Examination

QW-195.2.1: Terminology

- ❑ **Relevant Indications:** Indications with major dimensions greater than 1.5 mm.
- ❑ **Linear Indications:** An indication having a length greater than three times the width.
- ❑ **Rounded Indications:** An indication of circular or elliptical shape with the length equal to or less than three times the width.

QW - Welding (Article I)

QW-195 : Liquid Penetrant Examination

QW-195.2.2: Acceptance Criteria for Qualification

Procedure and performance tests examined shall be judged unacceptable when:

- a) Relevant linear indications.
- b) Relevant rounded indications greater than 3/16 in.(5 mm).
- c) Four or more relevant rounded indications in a line separated by 1/16 in. (1.5 mm) or less (edge-to-edge).

Article II

Welding Procedure Qualifications

QW - Welding

Article II: Welding Procedure Qualification

QW-200: General

QW-210: Preparation of test coupon

QW-220: Hybrid Welding Procedure Verifiable

QW-250: Welding Variables

QW-290: Temper Bead Welding

QW - Welding (Article II) WPS Qualification

QW-200: General (WPS)

QW-200.1: Each organization shall prepare written Welding Procedure Specifications (WPS). (**QG107:** It maybe transferred to another owner)

QW-200.1(a): A WPS is a written qualified welding procedure prepared to provide direction to Welder/Welding Operator for making production welds to Code requirements

QW-200.1(b): Variable for each process is listed in **QW-250** and defined in Article IV.

QW-200.1(c): Non Essential variable may change with out re-qualification but changes in Essential and Supplementary Essential variable will required re-qualification.

QW-200.1(d): See form no. **QW-482** for WPS format.

Guide for this format is given in **Non-mandatory Appendix B.**

QW - Welding (Article II) WPS Qualification

QW-200: General (WPS)

QW-200.2: Each organization shall prepare written Procedure Qualification Record (PQR).

QW-200.2(a): A PQR is a record of variable during the welding of test coupon.

QW-200.2(b):

- ☐ The PQR shall be certified accurate by the organization.
- ☐ The organization may not subcontract the certification function.
- ☐ This certification is intended to be the organization's verification that the information (Variables, Tensile, Bend etc) in the PQR is a true.

QW - Welding (Article II) WPS Qualification

QW-200: General (PQR)

QW-200.2(c): Changes to the PQR are not permitted except as:

- ☐ Editorial Corrections or Addenda to the PQR are permitted.
- ☐ An example of an Editorial correction is an incorrect P-Number, F-Number, or A-Number that was assigned to a particular base metal or filler metal.
- ☐ An example of an Addendum would be a change resulting from a Code change.

For example, Section IX may assign a new F-Number to a filler metal or adopt a new filler metal under an established F-Number

- ☐ All changes to a PQR require recertification (including date) by the organization.

QW-200.2(d): See form no. QW-483 for PQR format.

Guide for this format is given in **Non-mandatory Appendix B.**

QW - Welding (Article II) WPS Qualification

QW-200: General (PQR)

QW-200.2(e): Availability of the PQR

- ☐ PQRs used to support WPSs shall be available, upon request, for review by the Authorized Inspector (AI).
- ☐ The PQR need not be available to the welder or welding operator.

QW-200.2(f): Multiple WPSs with One PQR or Multiple PQRs with one WPS several WPSs may be prepared.

Example:

A single WPS may cover a thickness range from 1.5 mm through 32 mm if PQRs exist for both the 1.5 mm through 5 mm and 5 mm through 32 mm thickness ranges.

QW - Welding (Article II) WPS Qualification

QW-200: General

QW-200.3: (P No./Group No.)

☐ To reduce the number of welding procedure qualifications required, P-Numbers are assigned to base metals dependent on characteristics (**See Table QW-422**).

☐ Group Numbers are assigned additionally to P-Numbers.

These Group Numbers classify where toughness requirements are specified (**See Table QW-422**).

QW-200.4: Combination of Welding Procedures:

☐ More than one WPS may be used to weld single weld joint.

☐ **QW-451** shall be used to determine the range of Base Metal Thickness and Maximum Weld Metal Thickness qualified for each process, filler metal, or set of variables, and those limits shall be observed.

QW - Welding (Article II) WPS Qualification

QW-202: Type Of Tests Required (PQR)

QW-202.1: Mechanical Tests

- ❑ The type and number of test specimens that shall be tested to qualify a groove weld procedure are given in **QW-451**.
- ❑ Test sample shall be removed in a manner similar to that shown in **Figures QW-463.1(a) through QW-463.1(f)**.

QW - Welding (Article II) WPS Qualification

QW-202: Type Of Tests Required (PQR)

Table QW-451.1
Groove-Weld Tension Tests and Transverse-Bend Tests

Thickness <i>T</i> of Test Coupon, Welded, in. (mm)	Range of Thickness <i>T</i> of Base Metal, Qualified, in. (mm)		Maximum Thickness <i>t</i> of Deposited Weld Metal, Qualified, in. (mm)	Type and Number of Tests Required (Tension and Guided-Bend Tests) [Note (2)]			
	Min.	Max.		Tension, QW-150	Side Bend, QW-160	Face Bend, QW-160	Root Bend, QW-160
Less than $\frac{1}{16}$ (1.5)	<i>T</i>	$2T$	$2t$	2	...	2	2
$\frac{1}{16}$ to $\frac{3}{8}$ (1.5 to 10), incl.	$\frac{1}{16}$ (1.5)	$2T$	$2t$	2	[Note (5)]	2	2
Over $\frac{3}{8}$ (10), but less than $\frac{3}{4}$ (19)	$\frac{3}{16}$ (5)	$2T$	$2t$	2	[Note (5)]	2	2
$\frac{3}{4}$ (19) to less than $1\frac{1}{2}$ (38)	$\frac{3}{16}$ (5)	$2T$	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...
$\frac{3}{4}$ (19) to less than $1\frac{1}{2}$ (38)	$\frac{3}{16}$ (5)	$2T$	$2T$ when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...
$1\frac{1}{2}$ (38) to 6 (150), incl.	$\frac{3}{16}$ (5)	8 (200)	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...
$1\frac{1}{2}$ (38) to 6 (150), incl.	$\frac{3}{16}$ (5)	8 (200)	8 (200) [Note (3)] when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...
Over 6 (150)	$\frac{3}{16}$ (5)	$1.33T$	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...
Over 6 (150)	$\frac{3}{16}$ (5)	$1.33T$	$1.33T$ when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...

NOTES:

(2) For combination of welding procedures, see QW-200.4.

(4) see QW-151.1, QW-151.2, and QW-151.3 for details on multiple specimens when coupon thicknesses are over 1 in. (25 mm).

(5) Four side-bend tests may be substituted for the required face- and root-bend tests, when thickness *T* is $\frac{3}{8}$ in. (10 mm) and over.

QW - Welding (Article II) WPS Qualification

QW-210: Preparation Of Test Coupon (PQR)

QW-211: Base Metal

- ☐ base metals may consist of either plate, pipe, or other product forms.
- ☐ Qualification in plate also qualifies for pipe welding and vice versa.
- ☐ dimensions of test coupon shall be sufficient to provide the required test specimens. (6" Length).

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables

QW-251.1: Variables for each welding process are listed in **Tables QW-252 through QW-267**.

□ These variables are subdivided into Essential, Non-Essential and Supplementary Essential Variables.

Essential Variable QW-251.2	Non-Essential Variable QW-251.3	Supplementary Essential Variable QW-401.1
Considered to affect the mechanical properties of the weldment, and shall <u>require requalification of the WPS</u> (e.g.: Base Metal)	May be made in the WPS <u>without requalification</u> . (e.g. : Electrode Dia if $\varnothing > 6\text{mm_SMAW}$)	<u>Addition to the essential variables</u> for each welding process. (e.g.: Toughness Test)

Welding Variables Procedure Specifications (WPS) — Shielded Metal-Arc Welding (SMAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	A	.1 ϕ Groove design			X
		.4 - Backing			X
		.10 ϕ Root spacing			X
		.11 + Retainers			X
QW-403 Base Metals	B	.5 ϕ Group Number		X	
		.6 T Limits toughness		X	
		.8 ϕ T Qualified	X		
		.9 t Pass > $\frac{1}{2}$ in. (13 mm)	X		
QW-404 Filler Metals	C	.1 ϕ Base qualified	X		
		.4 ϕ F-Number	X		
		.5 ϕ A-Number	X		
		.6 ϕ Diameter			X
		.7 ϕ Diameter > $\frac{1}{4}$ in. (6 mm)		X	
		.12 ϕ Classification		X	
		.30 ϕ t	X		
QW-405 Positions	D	.1 + Position			X
		.3 ϕ $\uparrow$ Vertical welding			X
QW-406 Preheat	E	.1 Decrease > 100°F (55°C)	X		
		.2 ϕ Preheat maint.			X
		.3 Increase > 100°F (55°C) (IP)		X	

Table QW-253

Welding Variables Procedure Specifications (WPS) — Shielded Metal-Arc Welding (SMAW)

QW-407 PWHT	F	.1	ϕ PWHT	X		
		.2	ϕ PWHT (T & T range)		X	
QW-409 Electrical Characteristics	G	.1	> Heat input		X	
		.4	ϕ Current or polarity		X	X
		.8	ϕ I & E range			X
QW-410 Technique	H	.1	ϕ String or weave			X
		.5	ϕ Method cleaning			X
		.6	ϕ Method back gouge			X
		.7	ϕ Oscillation			X
		.8	ϕ Tube-work distance			X
		.9	ϕ Multi to single pass per side		X	X
		.10	ϕ Single to multi electrodes		X	X
		.15	ϕ Electrode spacing			X
		.25	ϕ Manual or automatic			X
		.26	± Peening			X
		.64	Use of thermal processes	X		

Legend:

+ Addition
- Deletion

> Increase or greater than
< Decrease or less than

↑ Uphill
↓ Downhill

← Forehand
→ Backhand

ϕ Change

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (**A**- Joints)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	A .1	Ø Groove Design			X
	.4	- Backing			X
	.10	φ Root Spacing			X
	.11	± Retainers			X

QW-402.1: A change in the type of groove (Vee groove, U-groove, single-bevel, double-bevel, etc.).

QW-402.4: The deletion of the backing in single welded groove welds. Double-welded groove welds are considered welding with backing.

QW-402.10: A change in the specified root spacing.

➡ Deletion of Backing for welder is essential (QW-353)

QW-402.11: The addition or deletion of nonmetallic retainers or non fusing metal retainers

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-403 Base Materials	B	.5 ϕ Group No.		X	
		.6 T limits Toughness		X	
		.8 ϕ T Qualified	X		
		.9 t Pass > 1/2 in. (13 mm)	X		
		.11 ϕ P-No. Qualified	X		

QW-403.5: (ϕ Group No.)

- ☐ Group number in welding assigned additionally to the P number materials.
- ☐ Divides P number for the purpose of welding procedure qualification when impact testing is a requirement by the construction code (**ASME VIII e.t.c**)

Table QW/QB-422
Ferrous and Nonferrous P-Numbers
Grouping of Base Metals for Qualification (Cont'd)

Spec. No.	Designation, Type, or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding		Brazing				
				Group		P-No.	AWS B2.2 BM	ISO 15608 Group	Nominal Composition	Typical Product Form
				P-No.	No.					
				Ferrous (Cont'd)						
A/SA-516	55	K01800	55 (380)	1	1	101	100	1.1	C-Si	Plate
A/SA-516	60	K02100	60 (415)	1	1	101	100	1.1	C-Mn-Si	Plate
A/SA-516	65	K02403	65 (450)	1	1	101	100	1.1	C-Mn-Si	Plate
A/SA-516	70	K02700	70 (485)	1	2	101	100	11.1	C-Mn-Si	Plate

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (**B**- Base Metal)

QW-403.6: (T limits Toughness) Supplementary Essential

When Impact test required, Minimum base metal qualified thickness will be:

- ☐ Thickness of test coupon (T) or 16.0 mm (Whichever is less)
- ☐ If thickness of test coupon (T) is $\leq 6.0\text{mm}$ then
Minimum qualified thickness is. $\frac{1}{2} T$.

➡ This variable does not apply when a WPS is qualified with a PWHT above the upper transformation temperature or when an austenitic or P-No. 10H (SA240 S31803 Duplex) material is solution annealed after welding.

➡ Lateral Expansion (**ASME VIII Div 1 UHX-51**) is to be checked when toughness test performed on duplex material.

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (**B**- Base Metal)

QW-403.8: (ϕ T Qualified) Essential

❑ Change in base metal thickness beyond the range qualified in QW-451 except as otherwise permitted by QW-202.4(b).

QW-202.4(b)(2): If test coupon thickness is $\geq 38.0\text{mm}$, There will be No limitation for maximum qualified thickness.

Table QW-451.1
Groove-Weld Tension Tests and Transverse-Bend Tests

Thickness T of Test Coupon, Welded, in. (mm)	Range of Thickness T of Base Metal, Qualified, in. (mm)		Maximum Thickness t of Deposited Weld Metal, Qualified, in. (mm)	Type and Number of Tests Required (Tension and Guided-Bend Tests) [Note (2)]			
	Min.	Max.		Tension, QW-150	Side Bend, QW-160	Face Bend, QW-160	Root Bend, QW-160
Less than $\frac{1}{16}$ (1.5)	T	$2T$	$2t$	2	---	2	2
$\frac{1}{16}$ to $\frac{3}{8}$ (1.5 to 10), incl.	$\frac{1}{16}$ (1.5)	$2T$	$2t$	2	[Note (5)]	2	2
Over $\frac{3}{8}$ (10), but less than $\frac{3}{4}$ (19)	$\frac{3}{16}$ (5)	$2T$	$2t$	2	[Note (5)]	2	2
$\frac{3}{4}$ (19) to less than $1\frac{1}{2}$ (38)	$\frac{3}{16}$ (5)	$2T$	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4	---	---
$\frac{3}{4}$ (19) to less than $1\frac{1}{2}$ (38)	$\frac{3}{16}$ (5)	$2T$	$2T$ when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4	---	---
$1\frac{1}{2}$ (38) to 6 (150), incl.	$\frac{3}{16}$ (5)	8 (200)	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4	---	---
$1\frac{1}{2}$ (38) to 6 (150), incl.	$\frac{3}{16}$ (5)	8 (200)	8 (200) [Note (3)] when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4	---	---
Over 6 (150)	$\frac{3}{16}$ (5)	1.33T	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4	---	---
Over 6 (150)	$\frac{3}{16}$ (5)	1.33T	1.33T when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4	---	---

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (**B**- Base Metal)

QW-403.8: (ϕ T Qualified) Essential

➡ Welding strengths vary according to plate thickness and distance from the weld root. The risk of brittle fracture increases with thickness. Cracks susceptibility is more likely to happen with high thickness and high resistance. Those facts and others, shown by research, demonstrate why base metal thickness is an essential variable.

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (**B**- Base Metal)

QW-403.9: [t Pass > 1/2 in. (13 mm)] Essential

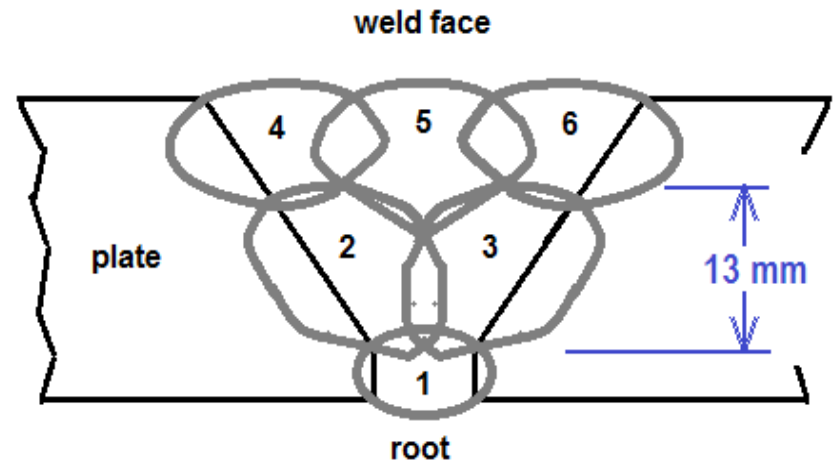
If any weld pass is greater than 13 mm thick.

Maximum qualified thickness will be 1.1 times of test coupon.

❑ Normally in SMAW, GTAW, GMAW, FCAW and SAW you don't exceed 13mm weld pass thickness.

❑ It is more common for Electrogas and Electroslag welding.

➡ If weld pass > 1/2 inch thick will have sufficient heat input to anneal the HAZ, thus reducing the tensile strength of the weldment, or increase the time the HAZ is exposed to temperatures > 1037°C, thus reducing the ductility of the weldment.



QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (**B**- Base Metal)

QW-403.11: (ϕ P-No. Qualified) Essential

Base metals shall be qualified using base metals in accordance with **Table QW-424**.

The **P number in welding** assigned to the material by **ASME** Code Section IX to reduces the **number of welding** procedure qualification.

► P numbers of SA335 ASME II-A and ASME IX are different.

ASME Sec II-A		ASME Sec IX
A/SA 335	P9	P5B
A/SA 335	P11	P4
A/SA 335	P22	P5A
A/SA 335	P91	P15E

Base Metal(s) Used for Procedure Qualification on**Coupon****Base Metals Qualified**

One metal from a P-Number to any metal from the same P-Number	Any metals assigned that P-Number
One metal from a P-Number to any metal from any other P-Number	Any metal assigned the first P-Number to any metal assigned the second P-Number
One metal from P-No. 15E to any metal from P-No. 15E	Any P-No. 15E or 5B metal to any metal assigned P-No. 15E or 5B
One metal from P-No. 15E to any metal from any other P-Number	Any P-No. 15E or 5B metal to any metal assigned the second P-Number
One metal from P-No. 3 to any metal from P-No. 3	Any P-No. 3 metal to any metal assigned P-No. 3 or 1
One metal from P-No. 4 to any metal from P-No. 4	Any P-No. 4 metal to any metal assigned P-No. 4, 3, or 1
One metal from P-No. 5A to any metal from P-No. 5A	Any P-No. 5A metal to any metal assigned P-No. 5A, 4, 3, or 1
One metal from P-No. 5A to a metal from P-No. 4, or P-No. 3, or P-No. 1	Any P-No. 5A metal to any metal assigned to P-No. 4, 3, or 1
One metal from P-No. 4 to a metal from P-No. 3 or P-No. 1	Any P-No. 4 metal to any metal assigned to P-No. 3 or 1
Any unassigned metal to the same unassigned metal	The unassigned metal to itself
Any unassigned metal to any P-Number metal	The unassigned metal to any metal assigned to the same P-Number as the qualified metal
Any unassigned metal to any metal from P-No. 15E	The unassigned metal to any metal assigned P-No. 15E or 5B
Any unassigned metal to any other unassigned metal	The first unassigned metal to the second unassigned metal

Table QW-424

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (C- Filler Metal)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
C QW-404 Filler Metals	.4	φ F-Number	X		
	.5	φ A-Number	X		
	.6	φ Diameter			X
	.7	φ Diameter > 1/4 in. (6 mm)		X	
	.12	φ Classification		X	
	.30	φ t	X		
	.33	φ Classification			X

QW-404.4: (φ F Number) Essential

A change from one F-Number in **Table QW-432** to any other F-Number or to any other filler metal not listed in **Table QW-432**.

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (C- Filler Metal)

QW-404.4: (ϕ F Number) Essential

- ➡ In **ASME IX** the procedure must be requalified if the F-number changes. (The F-number is also an essential variable for performance qualification. But it's not as restrictive as the welding-procedure specification. For welders using F-1 through F-4 electrodes, the higher F-number electrode qualifies the lower just like in **AWS D1.1**).

Usually F number is associated with an electrode specification.

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (C- Filler Metal)

QW-404.5: (ϕ A Number) Essential

- ☐ Change in the chemical composition of the weld deposit from one A-Number to any other A-Number in **Table QW-442**.
- ☐ Qualification with A-No. 1 shall qualify for A-No. 2 and vice versa.
- ☐ The weld metal chemical composition may be determined by any of the following:

QW-404.5(a): For all welding processes chemical analysis of the weld deposit taken from the procedure qualification test coupon.

- ☐ In lieu of an A-Number designation, the nominal chemical composition of the weld deposit shall be indicated on the WPS and on the PQR.

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (C- Filler Metal)

QW-404.5: (φ A Number) Essential

Qualification with A-No. 1 shall qualify for A-No. 2 and vice versa

Table QW-442
A-Numbers

Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)] and [Note (2)]					
		C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	0.20	0.30	0.50	1.60	1.0
2	Carbon-Molybdenum	0.15	0.50	0.40-0.65	0.50	1.60	1.0
3	Chrome (0.4% to 2%)-Molybdenum	0.15	0.40-2.00	0.40-0.65	0.50	1.60	1.0
4	Chrome (2% to 4%)-Molybdenum	0.15	2.00-4.00	0.40-1.50	0.50	1.60	2.0
5	Chrome (4% to 10.5%)-Molybdenum	0.15	4.00-10.5	0.40-1.50	0.80	1.20	2.0
6	Chrome-Martensitic	0.15	11.0-15.0	0.70	0.80	2.00	1.0
7	Chrome-Ferritic	0.15	11.0-30.0	1.00	0.80	1.00	3.0
8	Chromium-Nickel	0.15	14.5-30.0	4.00	7.50-15.0	2.50	1.0
9	Chromium-Nickel	0.30	19.0-30.0	6.00	15.0-37.0	2.50	1.0
10	Nickel to 4%	0.15	0.50	0.55	0.80-4.00	1.70	1.0
11	Manganese-Molybdenum	0.17	0.50	0.25-0.75	0.85	1.25-2.25	1.0
12	Nickel-Chrome—Molybdenum	0.15	1.50	0.25-0.80	1.25-2.80	0.75-2.25	1.0

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (C- Filler Metal)

QW-404.30: (ϕ t) Essential

A change in deposited weld metal thickness beyond that qualified in accordance with QW-451 for procedure qualification.

Table QW-451.1
Groove-Weld Tension Tests and Transverse-Bend Tests

Thickness T of Test Coupon, Welded, in. (mm)	Range of Thickness T of Base Metal, Qualified, in. (mm)		Maximum Thickness t of Deposited Weld Metal, Qualified, in. (mm)	Type and Number of Tests Required (Tension and Guided-Bend Tests) [Note (2)]			
	Min.	Max.		Tension, QW-150	Side Bend, QW-160	Face Bend, QW-160	Root Bend, QW-160
Less than $\frac{1}{16}$ (1.5)	T	$2T$	$2t$	2	...	2	2
$\frac{1}{16}$ to $\frac{3}{8}$ (1.5 to 10), incl.	$\frac{1}{16}$ (1.5)	$2T$	$2t$	2	[Note (5)]	2	2
Over $\frac{3}{8}$ (10), but less than $\frac{3}{4}$ (19)	$\frac{3}{16}$ (5)	$2T$	$2t$	2	[Note (5)]	2	2
$\frac{3}{4}$ (19) to less than $1\frac{1}{2}$ (38)	$\frac{3}{16}$ (5)	$2T$	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...
$\frac{3}{4}$ (19) to less than $1\frac{1}{2}$ (38)	$\frac{3}{16}$ (5)	$2T$	$2T$ when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...
$1\frac{1}{2}$ (38) to 6 (150), incl.	$\frac{3}{16}$ (5)	8 (200)	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...
$1\frac{1}{2}$ (38) to 6 (150), incl.	$\frac{3}{16}$ (5)	8 (200)	8 (200) [Note (3)] when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...
Over 6 (150)	$\frac{3}{16}$ (5)	$1.33T$	$2t$ when $t < \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...
Over 6 (150)	$\frac{3}{16}$ (5)	$1.33T$	$1.33T$ when $t \geq \frac{3}{4}$ (19)	2 [Note (4)]	4	...	...

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (E- Preheat)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-406 Preheat	E .1	Decrease > 100°F	X		
	.2	φ Preheat Maintenance			X
	.3	Increase >100°F		X	

QW-406.1: [φ t Decrease > 50°C)] Essential

A decrease of more than 100°F (55°C) in the preheat temperature qualified.

- As we can see, a decrease in preheat temperature higher than 100°F is considered to change mechanical properties.
(It also happens with inter-pass temperature)

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (F- PWHT)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-407 PWHT	F	.1 ϕ PWHT	X		
		.2 ϕ PWHT (T & T range)		X	

QW-407.1: (ϕ PWHT) Essential

When Required, A separate procedure qualification is required for each P number.

ASME B31.3 Table 331.1.1 Postweld Heat Treatment

(16)

P-No. and Group No. (BPV Code Section IX, QW/QB-420)	Holding Temperature Range, °C (°F) [Note (1)]	Minimum Holding Time at Temperature for Control Thickness [Note (2)]	
		Up to 50 mm (2 in.)	Over 50 mm (2 in.)
P-No. 1, Group Nos. 1–3	595 to 650 (1,100 to 1,200)	1 h/25 mm (1 hr/in.); 15 min min.	2 hr plus 15 min for each additional 25 mm (in.) over 50 mm (2 in.)
P-No. 3, Group Nos. 1 and 2	595 to 650 (1,100 to 1,200)		
P-No. 4, Group Nos. 1 and 2	650 to 705 (1,200 to 1,300)		
P-No. 5A, Group No. 1	675 to 760 (1,250 to 1,400)		
P-No. 5B, Group No. 1	675 to 760 (1,250 to 1,400)		
P-No. 6, Group Nos. 1–3	760 to 800 (1,400 to 1,475)		
P-No. 7, Group Nos. 1 and 2 [Note (3)]	730 to 775 (1,350 to 1,425)		
P-No. 8, Group Nos. 1–4	PWHT not required unless required by WPS		

QW - Welding (Article II) WPS Qualification

QW-250: Welding Variables (**H**- Technique)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
H QW-410 Technique	.1	φ String or weave			X
	.5	φ Method cleaning			X
	.6	φ Method back gouge			X
	.9	φ Multiple to single pass/side		X	X
	.25	φ Manual or automatic			X
	.26	± Peening			X
	.64	Use of thermal processes	X		

QW-410.64: (Use of Thermal Processes) Essential

Only Applicable in P-No. 11A (SA 333 Gr.8) and P-No. 11B (SA 517 Gr. F) base metals weld grooves for thicknesses less than 16mm.

☐ Manufacturer to prepare a WPS using those thermal processes.

(Also see Appendix **P of ASME IX**)

QW - Welding (Article II) WPS Qualification

QW-288: Tube-to-Tube Sheet qualification Essential Variables

Table QW-288.1
Essential Variables for Procedure
Qualification of Tube-to-Tubesheet Welding
(All Welding Processes Except Explosion
Welding)

Paragraph		Brief of Variables	
QW-402 Joints	.31	<	Ligament size
	.32	ϕ	Joint configuration
QW-403 Base Metals	.18	ϕ	P-Number or A-Number
	.32	ϕ	Tube thickness
	.33	<	Cladding thickness
	.34	ϕ	P-Number
QW-404 Filler Metals	.3	ϕ	Filler metal size
	.58	$\pm$	Preplaced filler metal
	.59	ϕ	A-number
QW-405 Positions	.3	ϕ	$\uparrow\downarrow$ Vertical welding
	.4	ϕ	Position
QW-406 Preheat	.1		Decrease >100°F (55°C)
	.3		Increase >100°F (55°C) (IP)

QW - Welding (Article II) WPS Qualification

Controlled Deposition Welding (CDW)

API 510_3.1.8: Any welding technique used to obtain controlled grain refinement and tempering of the underlying heat-affected zone in the base metal.

- ❑ Various controlled-deposition techniques, such as
 - a) Temper Bead (tempering of the layer below the current bead being deposited)
 - b) Half Bead (requiring removal of one-half of the first layer), are included.

CDW (Alternate to PWHT) When Impact Test Required as per UG-84 & UCS66

- ❑ Materials shall be limited to P-No. 1, P-No. 3, and P-No. 4 steels.
- ❑ Welding shall be limited to the SMAW, GMAW, and GTAW processes.

(See **API 510_8.1.7.4.3** for detail)

QW - Welding (Article II) WPS Qualification

QW-290: Temper Bead Welding

Table QW-290.4
Welding Variables for Temper Bead Procedure Qualification

Paragraph		Brief of Variables	Essential Variables [Note (1)]			Nonessential Variables
			A	B	C	
QW-402	.23	+ Fluid backing	X			
	.24	+ Fluid backing		X	X	
QW-403	.25	ϕ P-No. or Gr. No.		X	X	
	.26	> Carbon equivalent	X			
	.27	> T	X		X	
QW-404	.51	Storage				X
	.52	Diffusible hydrogen	X	X	X	
QW-406	.9	< Preheat temperature	X			
	.10	Preheat soak time				X
	.11	Postweld bakeout				X
QW-408	.24	Gas moisture				X
QW-409	.29	ϕ Heat input ratio	X	X	X	
QW-410	.10	ϕ Single to multiple electrode	X	X	X	
	.58	- Surface temper beads	X	X	X	
	.59	ϕ Type of welding	X	X	X	
	.60	+ Thermal preparation	X	X	X	
	.61	Surface bead placement	X	X	X	
	.62	Surface bead removal method				X
	.63	Bead overlap	X	X	X	
	.65	$\pm$ Grinding	X	X	X	

QW - Welding

Article III:	Welding Performance Qualification
QW-300:	General
QW-310:	Qualification Test Coupons
QW-320:	Retests and Renewal of Qualification
QW-350:	Welding Variables for Welders
QW-360:	Welding Variables for Welding Operators
QW-380:	Special Process

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-300: General

QW-300.1: This Article lists the welding processes separately, with the essential variables that apply to welder and welding operator performance qualifications.

- ☐ Welder qualification is limited by the essential variables given for each welding process.
- ☐ A welder or welding operator may be qualified by volumetric NDE of a test coupon or their initial production welding (With limitations of **QW-304** and **QW-305** or by bend tests taken from a test coupon.)
- ☐ For welder's or welding operator's qualification continuity it begins from welding date of test piece was completed and required testing was performed and the test results obtained were acceptable.

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-300: General

QW-301.1: Intent of qualification tests is to determine ability of welder to make sound weld.

QW-301.2: Welder or Welding operator who prepares the WPS qualification test coupons meeting the requirements of **QW-200** is also qualified within the limits of the performance qualifications.

QW-301.3: Each qualified welder and welding operator shall be assigned an identifying number, letter, or symbol by the organization.

It shall be used to identify the work of that welder or welding operator.

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-300: General

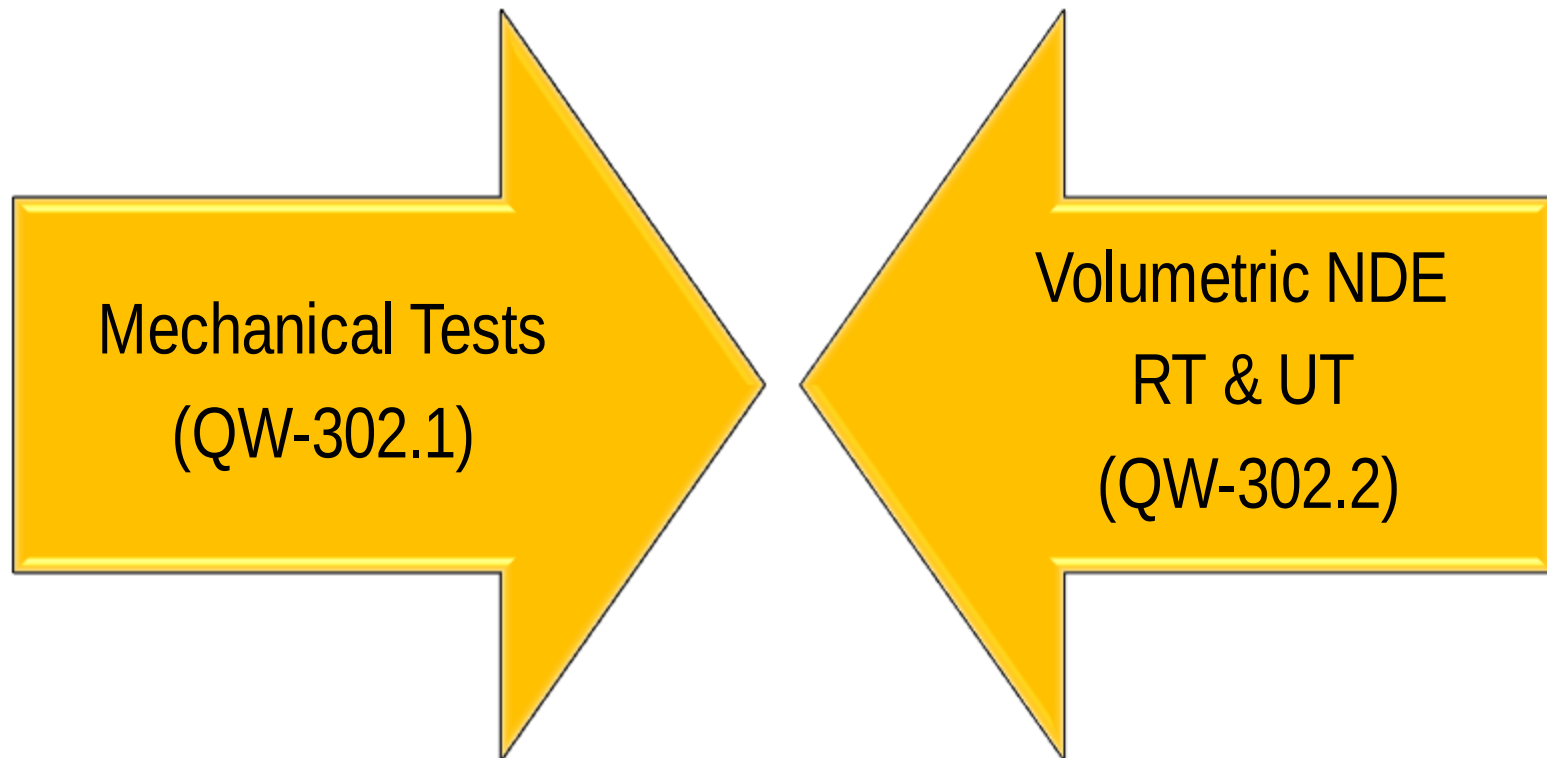
QW-301.4 : The record of Welder or Welding Operator Performance Qualification (WPQ) tests shall include following,

- a) Essential variables [**QW-350** (Welder) or **QW-360**(Welding Operator)]
- b) Type of test
- c) Test results
- d) Ranges qualified in accordance with **QW-452** & **Table QW-461.9**

Sample Forms given in **QW-484A/QW-484B** (see **No mandatory Appendix B**).

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-302: Types of Test Required



QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-302.1: Mechanical Tests

- ☐ See **Table QW-452 .1(a)** for type and required nos. of test specimens for mechanical testing.
- ☐ Groove weld test specimens shall be removed as per Figures **QW-463.2(a)** through **QW-463.2(g)**.
- ☐ Mechanical tests shall meet the requirements prescribed in **QW-150** (Tension Test) or **QW-160** (Bend Test) as applicable.

Table QW-452.1(a)
Test Specimens

Thickness of Weld Metal, in. (mm)	Type and Number of Examinations and Test Specimens Required			
	Visual Examination per QW-302.4	Side Bend QW-462.2 [Note (1)]	Face Bend QW-462.3(a) or QW-462.3(b) [Note (1)], [Note (2)]	Root Bend QW-462.3(a) or QW-462.3(b) [Note (1)], [Note (2)]
Less than $\frac{3}{8}$ (10)	X	...	1	1
$\frac{3}{8}$ (10) to less than $\frac{3}{4}$ (19)	X	2 [Note (3)]	...	...
$\frac{3}{4}$ (19) and over	X	2	...	...

GENERAL NOTE: The "Thickness of Weld Metal" is the total weld metal thickness deposited by all welders and all processes in the test coupon exclusive of the weld reinforcement.

NOTES:

- (1) To qualify using positions 5G or 6G, a total of four bend specimens are required. To qualify using a combination of 2G and 5G in a single test coupon, a total of six bend specimens are required. see QW-302.3. The type of bend test shall be based on weld metal thickness.
- (2) Coupons tested by face and root bends shall be limited to weld deposit made by one welder with one or two processes or two welders with one process each. Weld deposit by each welder and each process shall be present on the convex surface of the appropriate bent specimen.
- (3) One face and root bend may be substituted for the two side bends. For a test coupon welded in the 5G or 6G position, two face and two root bends may be substituted for the four side bends in accordance with Figure QW-463.2(d). For a test coupon welded using a combination of 2G and 5G positions, three face and three root bends may be substituted for the six side bends in accordance with Figure QW-463.2(f) or Figure QW-463.2(g).

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-302.2: Volumetric NDE (RT & UT)

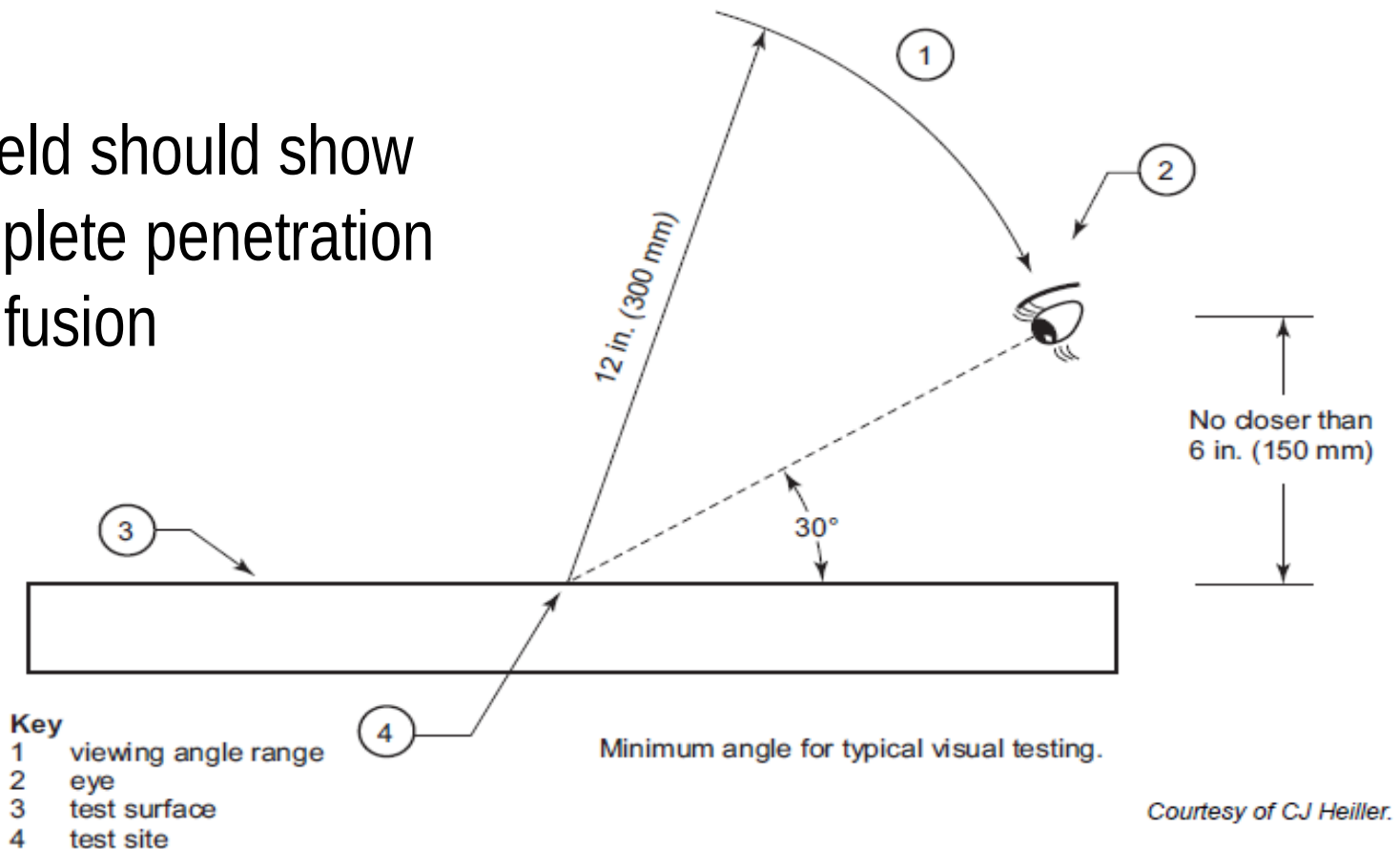
When the welder or welding operator is qualified by volumetric NDE. Following shall be meet,

- ☐ Minimum length of coupon(s) to be examined shall be 6 in. (150 mm). (1 Meter for Welding Operator)
- ☐ Entire weld circumference for pipe(s). (Maximum Requirement) (For 5G, 6G positions only)
- ☐ For Small diameter pipe, multiple coupons of the same diameter pipe may be required, but the number need not exceed four consecutively made test coupons.
- ☐ The examination technique and acceptance criteria shall be in accordance with **QW-191.**

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-302.4: Visual Examination

➡ Weld should show complete penetration and fusion



API 577 , Figure 14—Direct Visual Examination Requirements

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-302.3: Test Coupons in Pipe

□ For test coupons made on pipe in position 6G specimens shall be removed in accordance with **Figure QW-463.2(d)** or **Figure QW-463.2(e)** and all four specimens shall pass the test.

Figure QW-463.2(d)
Performance Qualification

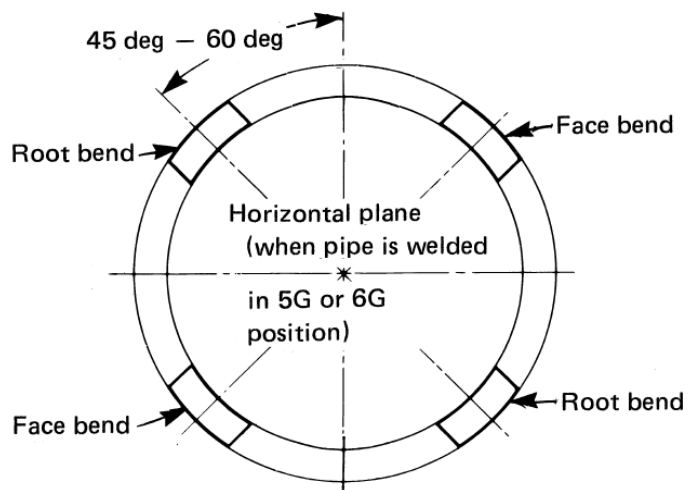


Figure QW-462.1(e)
Tension — Full Section — Small Diameter Pipe

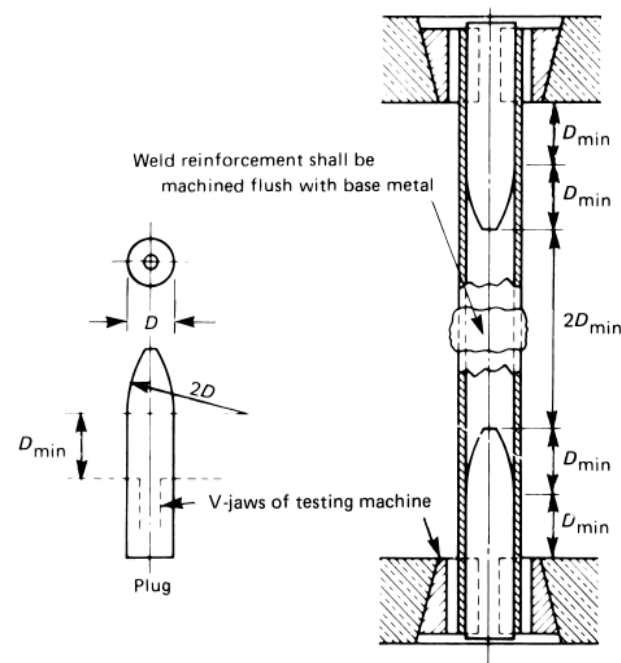
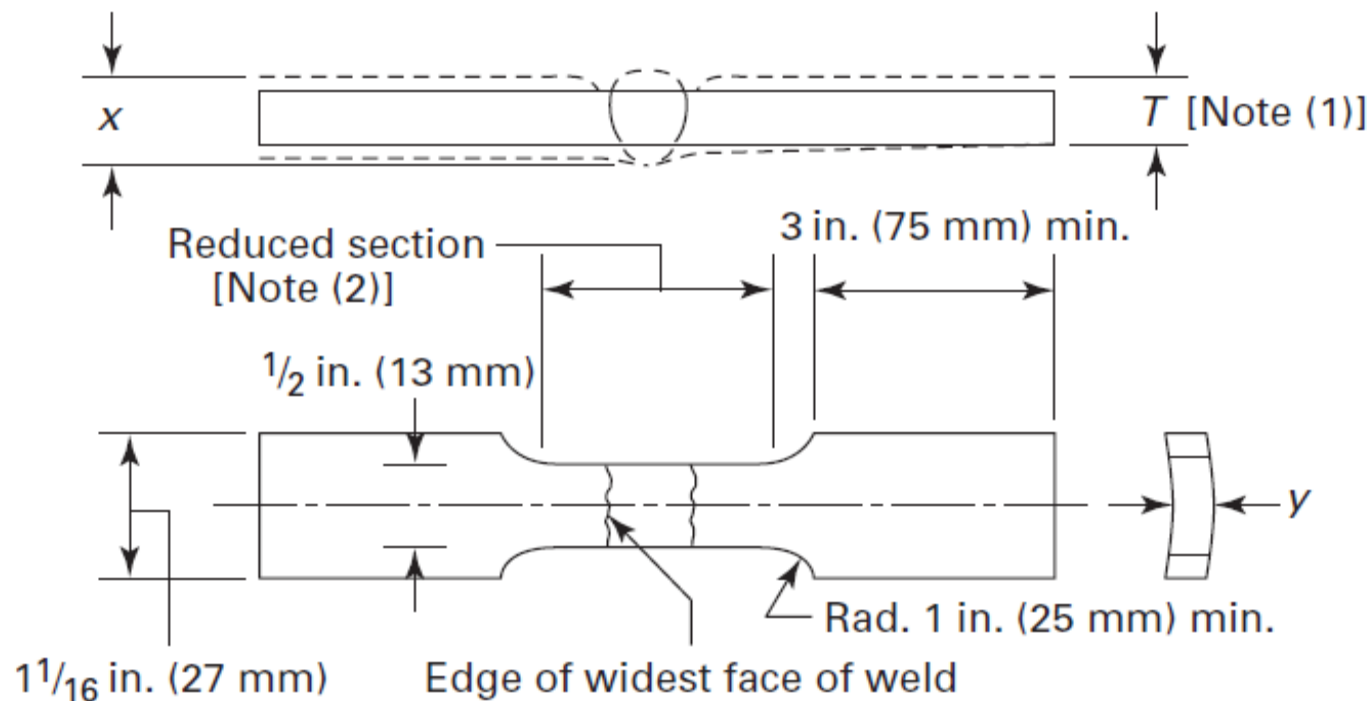


Figure QW-462.1(c)
Tension — Reduced Section Alternate for Pipe



NOTES:

- (1) The weld reinforcement shall be ground or machined so that the weld thickness does not exceed the base metal thickness T . Machine minimum amount to obtain approximately parallel surfaces.
- (2) The reduced section shall not be less than the width of the weld plus $2y$.

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-304 Welders

❑ Welders may be qualified by volumetric NDE when making a groove weld using SMAW, SAW, GTAW, PAW, and GMAW (except short-circuiting mode for radiographic examination) or a combination of these processes.

Except for P-No. 21 through P-No. 26, P-No. 51 through P-No. 53, and P-No. 61 through P-No. 62 metals.

➡ **11.3 _API 577 (Ed. Dec.13)**

Risk of LOF associated with GMAW-S means restrictions on qualification of welders using radiography. (This process normally use in low thickness)

Consequently, a higher standard of NDE inspection is required. In pipeline welding, automated ultrasonic has been adopted to overcome this problem.

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-304 Welders

☐ Welder qualified to weld in accordance with one qualified WPS is also qualified to weld in accordance with other qualified WPSs, using the same welding process, within the limits of the essential variables.

QW-304.1: Examination

☐ A minimum 6 in. (150 mm) length of the first production weld(s) made by a welder using the process(es) may be examined by volumetric NDE. (1 Meter for Welding Operator)

QW-304.1(a): For pipe(s) welded in the 5G, 6G, or special positions, the entire production weld circumference made by the welder shall be examined.

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-304 Welders

QW-304.1(b): For small pipes, multiple production weld of same diameter pipe may be examined, but the number need not exceed four consecutively made test coupons.

QW-304.1(c): The examination technique and acceptance criteria for production welds shall be in accordance with **QW-191**.

QW-304.2: Failure to Meet Examination Standards

If selected production weld for welder performance does not meet the examination standards, the welder has failed the test.

☐ In this event, entire production weld made by this welder shall be examined and repaired by a qualified welder or welding operator.

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-306: Combination Of Welding Processes

- ☐ Welders or welding operators using same or a different welding process, may be qualified in combination in a single test coupon.
- ☐ Failure of any portion of a combination test in a single test coupon constitutes failure of the entire combination.

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-310: Qualification Test Coupons Dimensions

Figure QW-469.1
Butt Joint

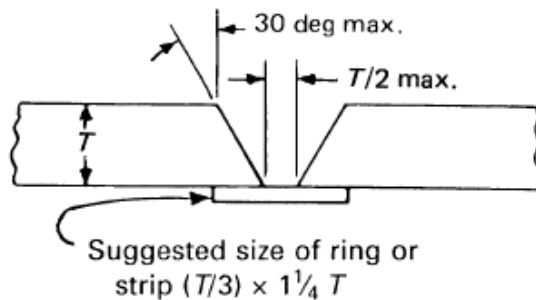
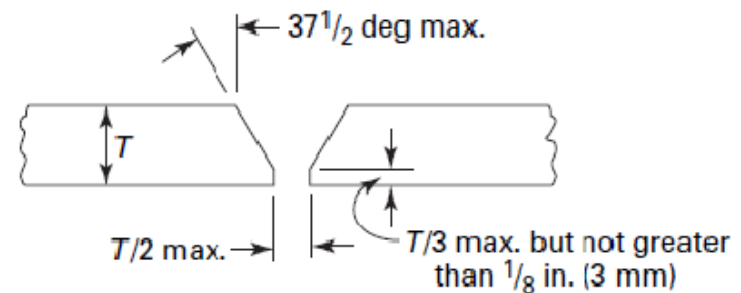


Figure QW-469.2
Alternative Butt Joint



➡ A single-welded groove-weld test coupon with backing or a double-welded groove-weld test coupon shall be considered welding with backing.

Partial penetration groove welds and fillet welds are considered welding with backing.

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-320: Retests & Renewal Of Qualification

QW-321: Retests

QW-321.1: Immediate Retest Using Visual Examination

☐ Two consecutive test coupons for each position which he has failed, all of which shall pass the visual examination requirements.

QW-321.2: Immediate Retest Using Mechanical Testing

☐ Two consecutive test coupons for each position which he has failed, all of which shall pass the test requirements.

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-320: Retests & Renewal Of Qualification

QW-321.3: Immediate Retest Using Volumetric NDE

☐ Retest shall be to examine two 6 in. (150 mm) plate coupons.

☐ For pipe, to examine two or more coupons of the same diameter for a total of 12 in. (300 mm) of weld.

which shall include the entire weld circumference for pipe or pipes (For small diameter pipe the total number of consecutively made test coupons need not exceed eight).

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-322: Expiration, Revocation & Renewal Of Qualification

QW-322.1(a): Qualification

Performance qualification remains valid,
No greater than 6 months have passed since the qualified welding
process last used.

QW-322.2(a): Renewal of Qualification

Renewal of qualification that has expired under the
rules of **QW-322.1(a)** may be achieved for any

- a) Process by welding
- b) Single test coupon of either plate or pipe,
- c) Material
- d) Thickness or diameter
- e) Position

as required by **QW-301** and successfully completing the testing required
by **QW-302**.

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-322: Expiration, Revocation & Renewal Of Qualification

QW-322.1(b): Revocation (Disqualification)

Specific reason to question the welder's or welding operator's ability.

QW-322.2(b): Renewal of Qualification

Renewal of qualification that has expired under the rules of **QW-322.1(b)**

Re-Qualification shall utilize a test coupon appropriate for the revoked qualification(s).

QW - Welding (Article III) (Welder/Welding Operator Qualification)

Welder I.D Card Sample

Welder Job Clearance Card		
Required by SAEP-324		
BI	BI-10-00450-0001	
Project	Manifa Core Hydrocarbon Facilities	
Welder Name	Ril Diaz	
Symbol	R 1112	
Note: This clearance card is for welding on the above mentioned project only, and may be revoked if welder's performance is not satisfactory. Card must be returned when welder is removed from this project		
PID Inspector  Mohammed Vajid Hussain		JCC No. 1,828 Date May 28, 2011

FRONT

Welder Job Clearance Card (Back)	
Saudi Aramco 4758-Eng (1/00)	
Material P-No's	P1 thru P15F, P34, P41 thru P49 to sam
Process	GTAW & SMAW
Elect./F-No's	ER 70S-2 & E 7018/F6 & F4 with backi
Position/Progress	All / Uphill
Thickness range	F6 max. 5.99mm/ F4 max. 5.99mm
Diameter range	2 7/8" OD & Above
Qualifying WPS	SAS-105/93
Supervisor Signature	 5/28/11 Keen, Peter D.
	
JCC No. 1,828	

BACK

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-350: Welding Variables For Welders

Table QW-353
Shielded Metal-Arc Welding (SMAW)
Essential Variables

Paragraph		Brief of Variables
A	QW-402 Joints	.4
		- Backing
B	QW-403 Base Metals	.16 ϕ Pipe diameter
		.18 ϕ P-Number
C	QW-404 Filler Metals	.15 ϕ F-Number
		.30 ϕ t Weld deposit
D	QW-405 Positions	.1 + Position
		.3 ϕ $\updownarrow$ Vertical welding

QW - Welding (Article III) (Welder/Welding Operator Qualification)

A QW-350: Welding Variables For Welders

QW-402.4 (Joints) [- Baking]: Deletion of backing is essential.

- ❑ Welders were qualified with backing so they are only allowed to weld on backing

B

QW-403.16 (Base Metal) [Ø Pipe Diameter]: A change in the pipe diameter qualified is essential

- ❑ Welders were qualified on plate so they can only weld on plate

Table QW-452.3
Groove-Weld Diameter Limits

Outside Diameter of Test Coupon, in. (mm)	Outside Diameter Qualified, in. (mm)	
	Min.	Max.
Less than 1 (25)	Size welded	Unlimited
1 (25) to $2\frac{7}{8}$ (73)	1 (25)	Unlimited
Over $2\frac{7}{8}$ (73)	$2\frac{7}{8}$ (73)	Unlimited

➡ $2\frac{7}{8}$ in. (73 mm) O.D. is the equivalent of NPS $2\frac{1}{2}$ (DN 65)

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-403.18 (Base Metal) [Ø P number]: A change in the P-No. material qualified is essential.

B

Table From QW-423

Base Metal(s) Used for Performance Qualification	Base Metals Qualified
P-No. 1 through P-No. 15F, P-No. 34, or P-No. 41 through P-No. 49	P-No. 1 through P-No. 15F, P-No. 34, and P-No. 41 through P-No. 49
P-No. 21 through P-No. 26	P-No. 21 through P-No. 26
P-No. 51 through P-No. 53 or P-No. 61 or P-No. 62	P-No. 51 through P-No. 53 and P-No. 61 and P-No. 62
Any unassigned metal to the same unassigned metal	The unassigned metal to itself
Any unassigned metal to any P-Number metal	The unassigned metal to any metal assigned to the same P-Number as the qualified metal
Any unassigned metal to any other unassigned metal	The first unassigned metal to the second unassigned metal

QW-404.15 (Filler Metal) [Ø F number] :

States a change in F-No. is essential.

C

Qualified With →	F-No. 1 With Backing	F-No. 1 Without Backing	F-No. 2 With Backing	F-No. 2 Without Backing	F-No. 3 With Backing	F-No. 3 Without Backing	F-No. 4 With Backing	F-No. 4 Without Backing	F-No. 5 With Backing	F-No. 5 Without Backing
Qualified For ↓										
F-No. 1 With Backing	X	X	X	X	X	X	X	X	X	X
F-No. 1 Without Backing		X								
F-No. 2 With Backing			X	X	X	X	X	X		
F-No. 2 Without Backing				X						
F-No. 3 With Backing					X	X	X	X		
F-No. 3 Without Backing						X				
F-No. 4 With Backing							X	X		
F-No. 4 Without Backing								X		
F-No. 5 With Backing									X	X
F-No. 5 Without Backing										X

Qualified With

Any F-No. 6

Any F-No. 21 through F-No. 26

Any F-No. 31, F-No. 32, F-No. 33,
F-No. 35, F-No. 36, or F-No. 37

F-No. 34 or any F-No. 41 through
F-No. 46

Any F-No. 51 through F-No. 55

Any F-No. 61

Any F-No. 71 through F-No. 72

Qualified For

All F-No. 6 [Note (1)]

All F-No. 21 through F-No. 26

Only the same F-Number as was
used during the qualification
test

F-No. 34 and all F-No. 41
through F-No. 46

All F-No. 51 through F-No. 55

All F-No. 61

Only the same F-Number as was
used during the qualification
test

Table From QW-433

also see table
QW-432 for F no.

QW-404.15 (Filler Metal) [Ø F number] :

C

➡ The F-number is also an essential variable for performance qualification. But it's not as restrictive as the welding-procedure specification. For welders using F-1 through F-4 electrodes, the higher F-number electrode qualifies the lower just like in **AWS D1.1**

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-350: Welding Variables For Welders

C

QW-404.30 (Filler Metal) [Ø t weld deposit]: States a change in the weld metal thickness qualified is essential.

Table QW-452.1(b)
Thickness of Weld Metal Qualified

Thickness, t , of Weld Metal in the Coupon, in. (mm)	Thickness of Weld Metal Qualified
All $\frac{1}{2}$ (13) and over with a minimum of three layers	$2t$ Maximum to be welded

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-405.1 [+ Position]: States a change in the position qualified is essential. (See **QW-303**)

Table QW-461.9

Performance Qualification — Position and Diameter Limitations (Within the Other Limitations of **QW-303**)

D

Qualification Test		Position and Type Weld Qualified		
		Groove		Fillet or Tack [Note (2)]
		Plate and Pipe Over 24 in. (610 mm) O.D.	Pipe ≤ 24 in. (610 mm) O.D.	Plate and Pipe
Weld	Position			
Plate — Groove	1G	F	F [Note (3)]	F
	2G	F, H	F, H [Note (3)]	F, H
	3G	F, V	F [Note (3)]	F, H, V
	4G	F, O	F [Note (3)]	F, H, O
	3G and 4G	F, V, O	F [Note (3)]	All
	2G, 3G, and 4G	All	F, H [Note (3)]	All
	Special Positions (SP)	SP, F	SP, F	SP, F
Pipe — Groove	1G	F	F	F
	2G	F, H	F, H	F, H
	5G	F, V, O	F, V, O	All
	6G	All	All	All
	2G and 5G	All	All	All
	Special Positions (SP)	SP, F	SP, F	SP, F

NOTES:

- (2) Tack welds are not limited by pipe or tube diameters when their aggregate length does not exceed 25% of the weld circumference.
 (3) Pipe 2⁷/₈ in. (73 mm) O.D. and over.

F = Flat
 H = Horizontal
 V = Vertical
 O = Overhead
 SP = Special Positions

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-350: Welding Variables For Welders

D

QW-405.3 (Position) [Ø↑↓ vertical welding]: States a change in the weld direction for vertical weld is essential.

(Uphill-Downhill)

❑ Change from upward to downward, or from downward to upward, in the progression specified for any pass of a vertical weld.

(except that the cover or wash pass may be up or down)

❑ The root pass may also be run either up or down when the root pass is removed to sound weld metal in the preparation for welding the second side.

QW - Welding (Article III) (Welder/Welding Operator Qualification)

QW-387: Tube-to-Tube Sheet Welder & Welding Operator Qualification

QW-387(a): Tube-to-tube sheet demonstration mockup qualification tests, QW-193.2 shall apply.

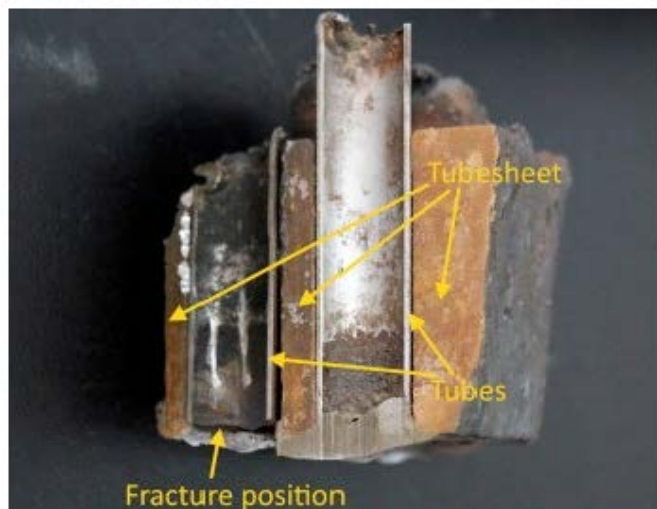
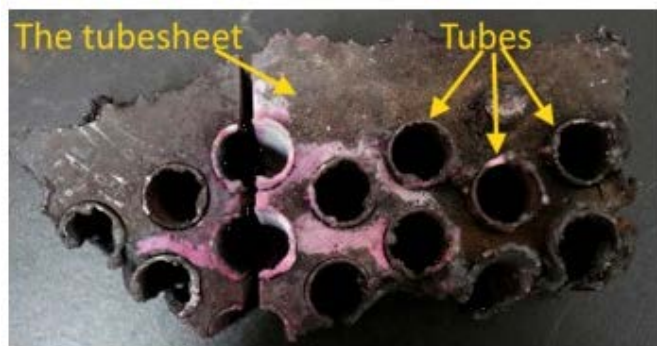


Table QW-388
Essential Variables for Tube-to-Tubesheet
Performance Qualification
(Welders; All Welding Processes)

Paragraph		Brief of Variables
QW-402 Joints	.31	≤ Ligament size
	.32	φ Joint configuration
QW-403 Base Metals	.16	φ Tube diameter
	.32	φ Tube thickness
QW-404 Filler Metals	.58	± Preplaced filler metal
QW-409 Electrical	.10	> Amperage

References:

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<http://apiexam.com/the-variables-on-a-wps-part-2/>

<http://apiexam.com/the-variables-on-a-wps-part-3/>

ASME sec. IX (Ed. 2019)

ASME Sec II part A (Ed. 2019)

ASME Sec II part D (Ed. 2019)

ASME Sec VIII Div. 1 (Ed. 2019)

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API 510 (Ed. 2014)

API 577 (Ed. 2013)

API 582 (Ed. 2009)

Thank You !